

JUNE 1942

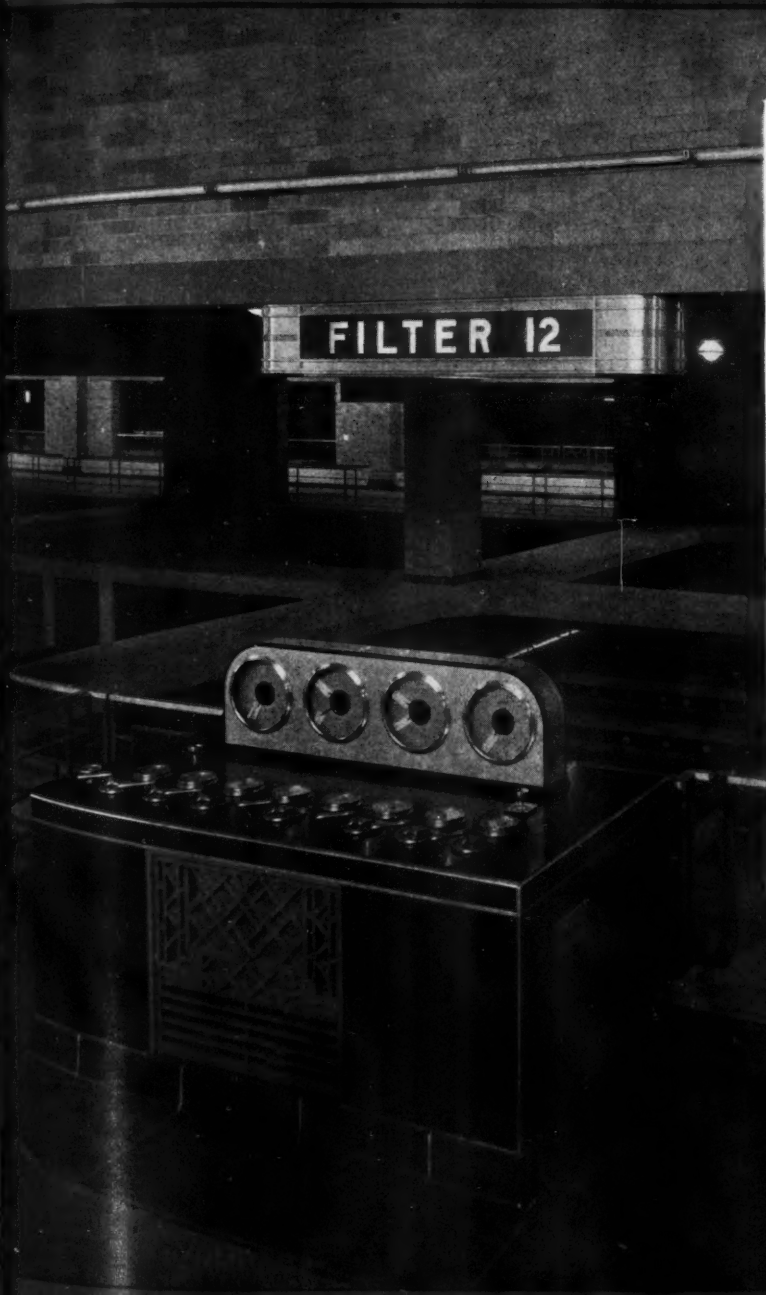
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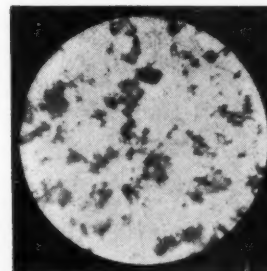
CLEVELAND, OHIO

TORONTO, ONTARIO

*POZZOLITH through CEMENT DISPERSION

Increases Cement Efficiency and Permits
Reduction of Water-Cement Ratio.

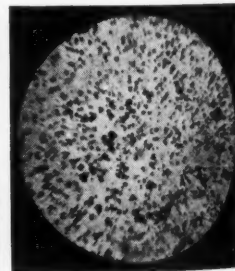
HOW CEMENT DISPERSION WORKS



Cement suspended in water
UNDISPERSED

WITHOUT POZZOLITH

In a normal concrete mix, cement particles tend to bunch together, thereby (1) limiting hydration and (2) trapping water within the cement clumps. (See photomicrograph above).



Cement suspended in water
DISPERSED

WITH POZZOLITH

Cement Dispersion drives these particles apart and (1) exposes their entire surface area to hydration, at the same time (2) making the water entrapped in the clumps available for lubrication of the mix. (See photomicrograph above).

MASTER BUILDERS

The WAR EMERGENCY

AS IT AFFECTS PUBLIC WORKS

Recent Restrictions on Copper and Steel Deliveries

Under date of May 23, Secretary Harry E. Jordan sent to various interested water works officials and manufacturers a communication in which he said:

"Conditions of utmost seriousness, resulting from recent War Production Board rulings (M-9-a and M-21-a) are now affecting the entire public water supply industry. Deliveries of copper bearing, and many alloy-steel bearing materials are restricted by these rulings to orders carrying a rating of A-1-k or better. This means that the preference ratings of A-2 or A-5 for maintenance and repair under order P-46 are of no practical value in obtaining anything which includes copper or certain grades of alloy steel. The only recourse at the moment lies in the filing of a PD-1A application for a rating of A-1-k or better for any unit of material or piece of equipment (required for construction, maintenance or repair of public water supply works) which contains copper or certain alloy steels. 'It is entirely possible that it may be necessary to appeal for a formal conference of War Production Board officials with the A.W.W.A. Defense Committee and the Manufacturers Emergency Committee.'"

Things are moving definitely toward an End Use Allocation of all critical metals, under a plan requiring every customer of a mill or foundry to file with his supplier full information as to the use to which material he asks for will be put, which information will be passed on to the War Production Board and be the basis upon which allocations of critical materials will be made. The purpose is to obtain standardization and reduce the number of different forms that industry now must submit to the WPB; and furnish the information needed by that board in allocating materials. This procedure may go into effect July 1.

Tin Can Salvaging Program

Some months ago word went out through the press that the War Production Board wished every one to salvage tins cans, along with steel, rubber, etc. Then thousands of householders began to ask what to do with the cans they had saved, and in many sections of the country no one could be found who would take them. Now it appears that "Because of transportation difficulties" (said Lessing J. Rosenwald, Chief of the Bureau of Industrial Conservation, on June 1st) "householders in the country at large can not be assured that tin cans they may collect can be disposed of unless they reside in one of the selected cities in which tin campaigns are to be launched."

Plans have now been made for tin can collection in 36 metropolitan areas, advantageously located for rail shipping to detinning and copper precipitation plants now in operation; which, however, have a maximum combined capacity of only 250,000 tons of tin cans a year. In 32 areas, householders will be asked to prepare the cans by cleaning, removing the label and both ends, and compressing slightly for shipment to detinning plants. In Los Angeles, Dallas, Houston, and Kansas City, Kans., and Kansas City, Mo., un-

prepared cans will be collected for shredding and delivery to copper mines.

The metropolitan centers selected to collect tin cans for detinning plants and to be asked to inaugurate collection programs are: Boston, Mass.; Hartford-New Britain, Conn.; Providence, R. I.; Springfield-Holyoke, Mass.; Lowell-Lawrence, Mass.; New York, N. Y.; Northern New Jersey; Albany-Schenectady-Troy, N. Y.; Philadelphia, Pa.; Scranton-Wilkes-Barre, Pa.; Baltimore, Md.; Washington, D. C.; Rochester, N. Y.; Buffalo, N. Y.; Pittsburgh, Pa.; Youngstown, Ohio; Cleveland, Ohio; Detroit, Mich.; Columbus, Ohio; Cincinnati, Ohio; Louisville, Ky.; Indianapolis, Ind.; Chicago, Ill.; Milwaukee, Wis.; Minneapolis, St. Paul, Minn.; St. Louis, Mo.; Denver, Colo.; Atlanta, Ga.; Birmingham, Ala.; New Orleans, La.; San Francisco, Calif.; Seattle, Wash.; and Portland, Oregon.

Flight Strips to Be Built

In 1941 Congress appropriated \$10,000,000 for flight strips. So far the program for these has progressed slowly, but it is stated that actual construction of some will be begun in a few weeks. Location of them is not to be made public. The number to be constructed in any given area will be decided by the Army Air Forces.

Each flight strip must have an area providing for, as a minimum, one runway 150 x 3,000 ft. for pursuit aircraft, and 150 x 4,000 ft. for all other military aircraft—longer at high altitudes. Where possible the area will be 1800 x 8,000 ft. The runways will be laid out in the direction of the prevailing winds where topography permits, and have a grade of not over 1%.

The heaviest wheel loads on the runways will probably be those due to bombing planes, these being 60,000 lb. static load, 70 lb. tire inflation, impact factor of 25%, giving a load of 583 lb. per sq. in. with a factor of safety of 1.2. A safe glide path should extend beyond the flight strip area in the direction of the center line of the runway for a distance of two miles, this path being 4,000 ft. wide at the far end and 300 ft. wide at the flight strip boundary—1,000 ft. for instrument landing; and within this path no obstacles should extend above a glide angle of 40 ft. horizontal to 1 vertical.

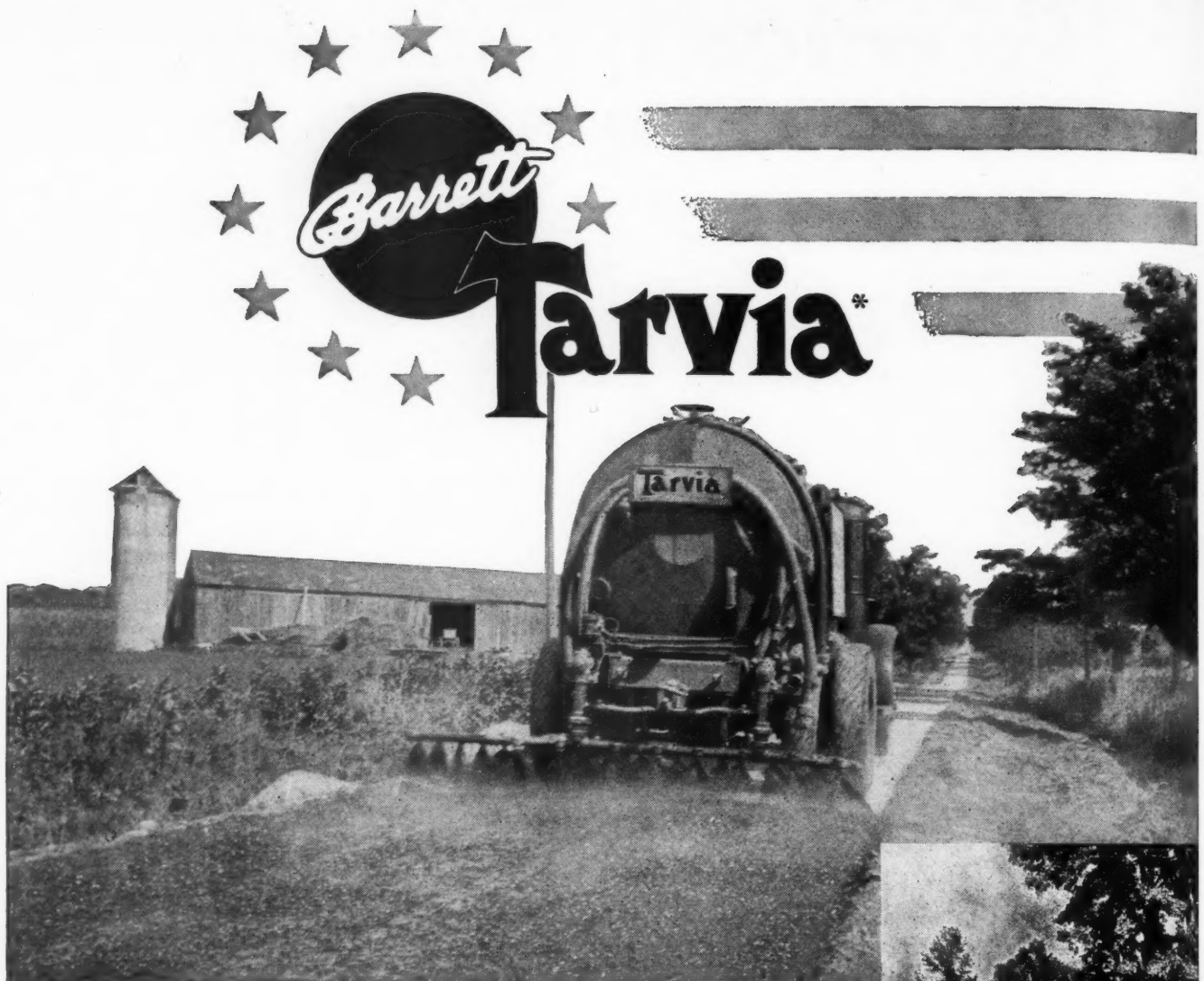
Approved Projects in Region I

Federal Works Agency reported on May 19th that a reexamination of construction projects in Region I—New England, New York, New Jersey and Pennsylvania—is to be made with a view to side-tracking for the duration all pending public works projects that are not indispensable.

The works that have been approved in this district include 26 water systems, 23 sewer systems and 131 hospitals, schools and recreation facilities. For schools and hospitals that are found essential, temporary one-story frame structures will be required in many cases.

Engineers' War Production Conferences

At the request of the War Production Board, engineering societies will hold a series of war production conferences in different sections of the country "to exchange, examine and disseminate information and experience on the engineering and management aspects of war production problems." The first conference was held at Newark, N. J., on May 29.



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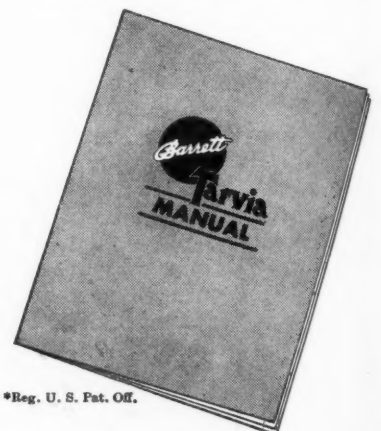
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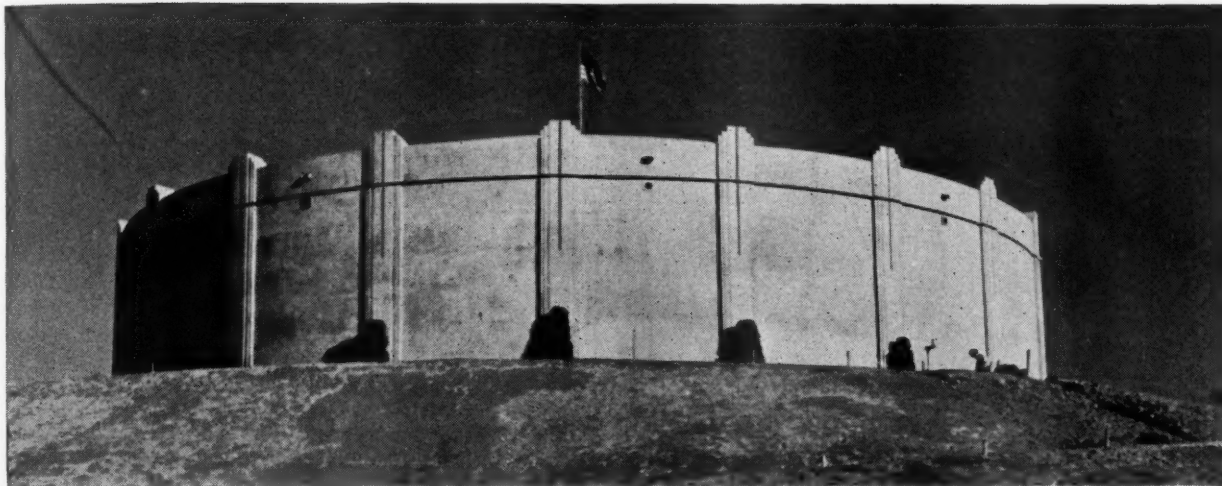
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When you need special information—consult the classified READER'S SERVICE DEPT., pages 81-83



General view of one of the reservoirs. A view from higher up, on page 12, shows the dome.

Council Bluffs, Iowa, Constructs Two Concrete Reservoirs

Similar reservoirs, each 106 feet diameter and 30 feet high, are placed on adjacent hills. Constructed with pre-stressed reinforcement and with flat dome roof.

TWIN concrete reservoirs, each of two million gallons capacity, are replacing an uncovered and structurally unsound reservoir that has supplied water to Council Bluffs, Iowa, for several years. One of the reservoirs has been completed by the Work Projects Administration and is in use, while on an adjacent hill construction is in progress on the second concrete structure. When completed, both tanks will be 236 feet above the level of the town, maintaining a pressure of 85 to 90 pounds throughout the business district.

The tanks have an inside diameter of 106 feet, with a height to overflow of 30 feet and a dome rise of $13\frac{1}{2}$ feet. The specifications call for vertical joints in the walls, and definitely exclude horizontal joints, making this type of construction similar to a barrel. Pre-stressed steel bands in the wall, placed around a first thickness of 15 inches of concrete and covered with $4\frac{1}{2}$ inches more on the outside, make a $19\frac{1}{2}$ -inch wall in which tension in the concrete is eliminated.

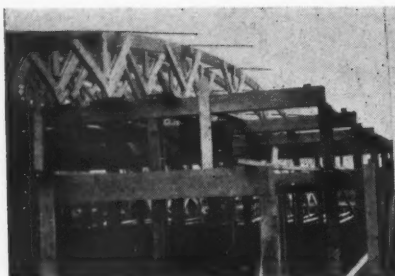
In construction of the first tank, 15 feet of dirt was removed from the top of the hill to bring it down to a level with the site for the second tank. Excavation for the footings was made on good bearing ground, and the footings were poured annularly 4 feet wide

and 12 inches thick. The floor was then poured in concentric circles from the outside to the center, $7\frac{1}{2}$ inches thick. All joints in the floor were depressed and the space filled with mortar before the tank was placed in service.

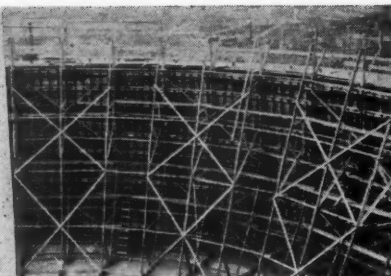
The inner 15-inch wall was poured to a full height of 30 feet. Three-tenths of the periphery was formed at one time. The forms were made of panels approxi-



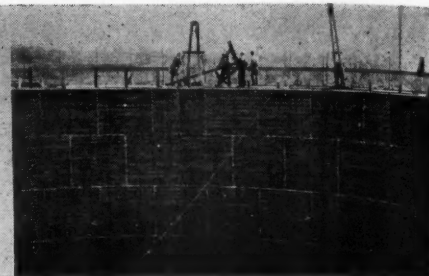
Placing the concrete floor in concentric rings.



Framing for dome construction.



Interior of forms for the 15-inch wall.



15-inch wall after forms have been removed.

mately 8 feet square, constructed of 2 by 6-inch studs and three-quarter inch sheathing, with the top and bottom plates cut to radius. The panels were held to line and plumb by wood frames bolted to the floor and extending up the full height of the wall forms.

In placing the concrete, one-tenth of the circumference was poured at one time, from the floor line to the top of the wall. The concrete was placed through holes 16 inches square, cut in the outer face of the form, in approximately 8 foot lifts. The concrete was vibrated through these holes by a mechanical vibrator.

After the pour had been completed on three-tenths of the circumference, the panel forms were removed and placed in the next location around the circle. After three moves, sufficient panels were erected to complete

In constructing the dome, the framing was supported on 111 wood posts, consisting of three 2 x 6's nailed together to form an "H." These posts were topped with double 2 x 10-inch girders. The joists were cut to radius and assembled on the ground, with struts under the joints, wedged up on the girders when erected.

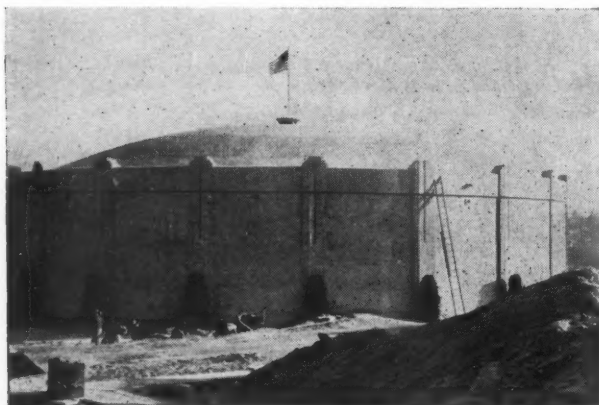
A dome ring bearing directly on top of the wall, but separated by an asphalt joint, was placed in one pour, extending approximately 8 inches in on the dome curve, where a construction joint was made.

Before pouring the dome, nine steel bands were prestressed around the dome ring. The dome itself was poured in three sections, concentrically, the outer section being poured first. A manhole was left next to the dome ring wall, through which the form lumber was passed after stripping, and which will serve as an entrance, with a steel ladder leading from it to the floor.

All forms used in construction of the first tank were so fabricated and numbered that they could readily be assembled for building the second tank.

Before the tank was placed in operation, all floor joints and vertical wall joints were filled with mortar, and the entire inner surface was given several coats of metallic water proofing. The walls are designed to withstand the static pressure of 30 feet of water without leakage.

This reservoir was designed by William S. Hewett in cooperation with F. B. Jensen, Superintendent of the Council Bluffs Water Works and constructed by the WPA. General foreman for the WPA was R. P. Tellander.



View of one completed reservoir, showing dome.

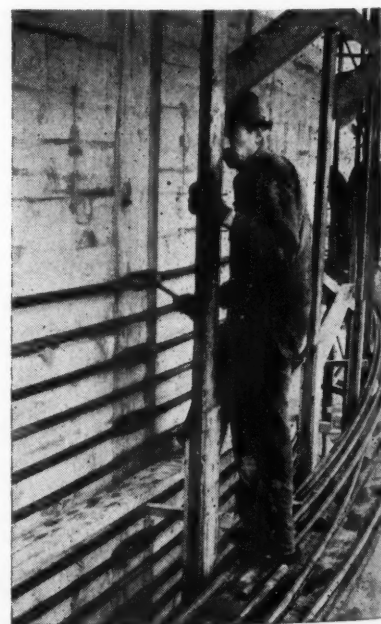
closure of the remaining section of the wall and the final pour was made.

With hardening of this shell, 74 round steel bands, $1\frac{3}{8}$ inches thick, each consisting of ten rods connected by turnbuckles, were placed around the wall and prestressed by means of the turnbuckles. The spacing of these bands varied from 3 inches, center to center, at the bottom to 12 inches at the top.

The $4\frac{1}{2}$ inches of concrete outer wall protects the round bands from corrosion. Forms for this wall were 4 by 15 feet, and were made of 2 by 4-inch studs and three-quarter inch sheathing, lined with three-eighth inch wood panels glued to the sheathing. The concrete was poured in lifts of 3 feet 10 inches, the forms being moved up as the work progressed.

Eighteen vertical spaces were left when the outer thickness was placed and pilasters were poured in these openings, from below the ground line to a point slightly above the top of the dome ring. The pilasters break the severe line of the dome ring and give a more pleasing appearance.

Placing and tightening the steel bands around the 15-inch wall. Other bands are lying on the ground at the right.



Base Stabilization With Soil as Stabilizing Agent

By MALOY QUINN

County Engineer, Clay Co., Kans.

How Clay County, Kans., improved twenty miles of road using crushed stone, sand and clay for base, followed later by a bituminous armor coat.



In Kansas it takes a lot of water to keep the road material moist.

CLAY COUNTY, Kansas, is devoted entirely to diversified farming; consequently, roads and particularly county roads are of prime importance to our rural county. For several years we have been striving to improve, and give all-weather surfacing to, our county system, which consists of 173 miles of road connecting with other county highways or state highways. With the exception of 9 miles, the entire 173 miles have been surfaced either with gravel, crushed stone, or bituminous mat. At this time there are 45 miles of bituminous surfacing and 119 miles of crushed rock and sand-gravel.

Some years ago we experimented with base stabilization using salt, which proved satisfactory. However, having a definite need for base stabilization and, as usual, a very limited budget, we decided in 1939 to try our most abundant and easily obtained local materials, stone, sand and clay, choosing clay, as the soil stabilizing agent, because of its quantity and high quality. At that time we constructed four miles of such road, all of which proved economical and satisfactory, and since then have constructed or have under construction twenty miles of this type of base.

The procedure we have followed has been to submit to the Work Projects Administration a proposal for the production and delivery of the aggregate, consisting of 1,000 yards of crushed stone, approximately 400 yards of sand-gravel and fine sand, and 200 yards of clay per mile. This makes a good winter job and covers a period when labor is very plentiful. In early spring, after the aggregate has been delivered, manipulation is carried out. Then during the summer months a bituminous armor coat is placed on the base consisting of 0.5 gallon of MC penetration and 0.3 gallon of AC seal coat, with 135 yards of sand-gravel cover coat, if funds are available.

Construction Procedure: We deliver 1,000 cubic yards of straight crusher-run, 1½-inch maximum size crushed stone per mile, delivered in a windrow on a previously graded and drained road. Then tests are run at ¼-mile intervals and from these tests the total aggregate is calculated. The combined aggregate is kept within the following limits:

Percent passing	1" Sieve	80% to 100%
	¾" Sieve	65% to 85%
	⅜" Sieve	45% to 80%
	No. 28 Sieve	18% to 35%
	No. 48 Sieve	12% to 27%
	No. 100 Sieve	9% to 20%
	No. 200 Sieve	5% to 15%

In determining the amount of coarse and fine sand and clay to be used, tests of the sand and gravel are made and such combinations of these are added to the stone as will give a combined aggregate meeting the specifications stated above, attempting to stay as near as possible to the center of the above limits. Then a combined sample of the material in the percentages determined is tested to ascertain what the combination of real materials will result. So far we have found the theoretical combination checks very close to the actual.

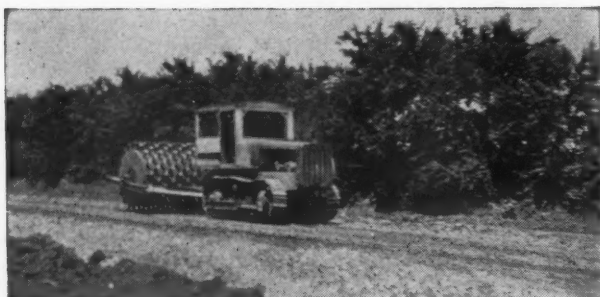
We find that limestone produces approximately 4 to 5% dust which will pass a 200-mesh sieve. In attempting to keep the silt and soil passing the 200-mesh sieve at approximately 15%, we arbitrarily add sufficient clay to the aggregate to give this figure. As a typical example, on our last section the final mix totaled 1,000 cubic yards of rock which averaged 65% of the total aggregate, 200 cubic yards of gravel—gradation 4.07—representing 13% of the total aggregate, 150 yards of bank run sand—gradation 1.56—



Final rolling of base. Water truck just passed.

Base before asphalt was placed.

Asphalt surface in place.



The roller feet are riding high.



Final rolling with smooth-faced roller.

representing 10% of the total aggregate, and 12% of clay, 100% of which passed the 200-mesh sieve (wash test). The plastic index of this clay was 22. The plastic index of the combined mix was 5.2. This total aggregate gave us approximately four inches of stabilized base 22 feet wide.

In construction, this material is mixed with a blade grader, maintainer, harrow, and disc until it is a homogeneous mass. Then approximately one-half is spread 22 feet wide over the prepared road surface, moistened and thoroughly rolled with a sheepfoot roller, after which it is maintained continuously to keep it smooth and uniform. After the first half has been thoroughly compacted, the balance of the aggregate is spread and the same procedure is followed until the sheepfoot roller rides, then a smooth-faced roller is used for the final rolling. During the rolling with the smooth-faced roller, only a minimum of maintenance is done. Throughout the operation the surface is kept moistened to obtain compaction and density.

After the surface has been rolled and compacted, the shoulders of the road bed are pulled, and rolled with a smooth roller so that the earth shoulder is well knitted to the laid base. After this, traffic is permitted to travel on it from three to six months, depending upon the time of the year. Rolling of this surface with a smooth roller is carried on periodically until the armor coat has been put in place. We find that by permitting traffic on the road before putting on the armor coat, all of the soft spots or other sources of later failures are brought out. These are repaired, as they appear, with the same mixture of aggregate as the original base. We have one section ten miles long which has been used without armor coat for eleven months and is very good. We use ordinary maintenance on it, attempting to maintain it while still wet and rolling after each rain.

The armor coat is that type of asphaltic surface called "single asphalt surface treatment," by our State Highway commission and is built according to its specification. It consists of a 0.5 gallon prime coat of medium curing asphaltic oil, permitted to penetrate the stabilized base until thoroughly absorbed; then sealed

with 0.3 gallon of asphalt cement, AC-3, and immediately covered with 135 cubic yards of surface treatment aggregate per mile. This aggregate in this section of the country is a sand-gravel having a high gradation. It is then rolled and dragged with a smooth roller and broom drag.

This gives a very satisfactory county highway; with a minimum of repair, it does not require attention for from three to five years, when it should be sealed again. It will carry from 300 to 600 vehicles per day without additional maintenance. Our people seem to like this type of road very much, and it works into our program extremely well, helping us to provide work-relief projects and getting a high type of surface on our county highways.

The cost to the county not including W.P.A. funds, averages just over \$1,000 per mile. The only change in the procedure this year from last year is to increase the depth of the base by using approximately 2,000 cubic yards of aggregate. This, we hope, will give longer life to the surface.

Cathodic Protection of Pipes in 1941

The protection of pipe lines from corrosion by a cathodically applied external current was first undertaken about 1910 or earlier. Since that time this system of protection has been widely extended, especially within the last ten years. According to a recent estimate, there are at present 750 cathodic protection units protecting 3000 miles of pipe line.

Sufficient experience has been accumulated to show that the protection of transmission lines is both practical and economical. It has even proved successful in protecting distribution systems in the few cities in which it has been tried, but because of interlacing networks this problem is, of course, much more difficult. Failures in the operation of cathodic protection which have been reported appear to be attributable to poor design and poor maintenance. Such failures are to be expected in any pioneering undertaking and are not to be taken too seriously.

An immediate problem in cathodic protection is the accurate determination of the minimum protective current density in order to insure that the pipe line is neither over nor under protected. In regulating the applied current, most companies are guided by the potentials of their pipe with respect to the earth, which is a rule-of-thumb method at best.

From what source the protective current should be obtained and how it should be applied to the pipe line are questions which will be answered by studies of costs to be determined by the engineer. Cost studies must also be made by the engineer in deciding whether a new line which is to receive cathodic protection should be coated before it is laid, and whether a corroding pipe line should be reconditioned or protected cathodically. *Abstract of a paper by Kirk H. Logan before the Engineers Society of Western Pennsylvania.*

Salvaging at Birmingham, Ala.

Birmingham, Ala., reports that 90,000 pounds of tin cans and 60 tons of paper, rags and rubber are salvaged each week from its rubbish, a salvage firm contracting to do this and pay the city for the privilege. In addition, more than 250 tons of salable scrap was collected from householders in a recent campaign and sold at \$13 a ton, the proceeds from which were turned over to the city's civilian defense organization.



Beginning excavation at top of header. Shows header planks and bracing.



Where two linings met coming from shafts 1100 feet apart.

Terre Haute Constructs Sewer by Tunneling to Avoid Inconvenience to the Public

By ROBERT E. GIBBONS
City Civil Engineer of Terre Haute, Ind.

Construction methods employed in tunneling a mile of 96-inch sewer 28 to 42 feet deep in an important street, at a cost less than that estimated for open trenching.

THE constant growth of Terre Haute, Ind., has resulted in such overloading of the present sewer system, in which both storm water and house sewage are carried, that during heavy rains water and sewage back up into streets and basements and create unsanitary conditions.

After a careful survey of all phases of the problem, it was decided to begin the solution of the problem by constructing on Walnut St. a new trunk sewer, 96 inches inside diameter and ranging in depth from 42 feet to 28 feet, designed as a 3-ring circular brick sewer, 6,891.66 ft. long. Also to build, as an extension of this on Ohio and Hulman Streets, 730 ft. of an 84-inch inside diameter, 2-ring brick sewer.

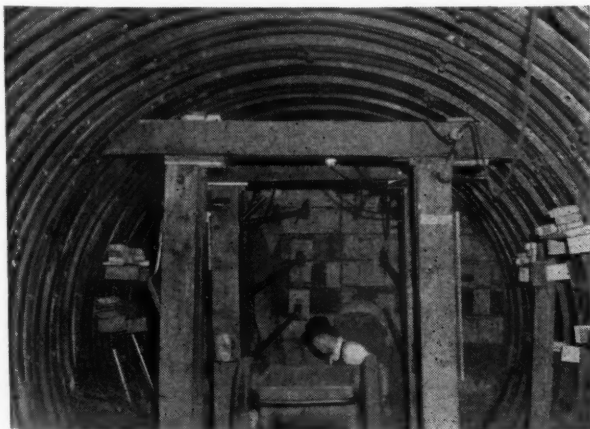
Walnut Street has a number of business houses on it, but for the main part is a thickly settled resi-

dential area. To build a wide, deep trench would have necessitated closing the street and causing great inconvenience to all the people living along it. Also several important, heavily traveled cross streets would have been subjected to delays, hazards and inconvenience.

For these reasons, serious consideration was given to the construction of this sewer by tunneling. A study of soil and water conditions indicated that no air pressure would be needed for tunneling; costs were roughly estimated to be about \$90 a foot as against \$114 a foot by open-trenching; and that method was adopted for that section of Walnut Street extending from the high ground just west of First Street to the east property line of Tenth and one-half Street. This section included the heavy traffic business district and all the railroad crossings, and also the deepest portion of the sewer. The remainder was not more than 28 to 30 feet deep and was planned as open cut. This program entailed the tunneling of about 5,000 feet.

Shafts.—Pits or shafts were sunk at intervals of from 1,100 to 1,200 feet. These shafts were lined from the top, as the excavation deepened, with corrugated metal liner plate having an inside clear diameter of 15 feet. Substantial stairs were built to give the workmen safe access to the tunnel 40 or more feet below. At one side of the shaft an elevator was constructed for removing excavated material and for admitting liner plates, brick and other materials, which proved safer and more convenient as well as more economical than using a crane or similar method for removing muck.

Taking a leaf from the experience of nearby coal



Shows header shield and bracing, with liner plates leading up to it.



Robert E. Gibbons,
City Engineer

mines, tipples were erected over the shafts to protect them from the weather and to prevent anyone from falling in. A simple hoisting engine lifted the muck carts to the "second floor," where they were emptied into a hopper capable of holding more excavated material than was produced by one shift. This made it unnecessary for trucks to be waiting or be on duty at night.

Mining Methods.—The moist, running, gravelly sand through which the tunnel passed required special precautions to keep the material from flowing in and undermining the pavement above.

The method consisted of building up a heading of short, heavy planks or breast boards braced against a substantial frame. Beginning at the top, one of these header planks was removed, a little excavating done and then 1-inch poling boards, 6 inches wide by 30 inches long, were inserted outside the diameter of the tunnel with the back end resting on the preceding liner plate and the front end wedged into the solid material ahead. A layer of hay helped to prevent the sand from coming through the cracks between the boards. As soon as enough poling boards were in place, the material in the heading was removed to a depth of $1\frac{1}{2}$ or 2 feet, hay laid against the front of the heading plank, and the plank was braced into place. Then the adjacent portion of the heading was similarly advanced. When this excavation had been extended over a sufficient part of the circumference (5 feet or more) a liner plate was placed in position and bolted onto the preceding plates.

These liner plates were of the heavy-duty corrugated type, 18 inches wide, with flanged edges, and 56 inches net length. Both "Commercial" and "Armco" liner plates were used. Nuts are welded to the outside of the longitudinal seams which make it easy to bolt the plates together.

The poling, excavating, bracing and plate bolting operations were repeated until a complete 10-foot-diameter circle was constructed. Then work was started on the next ring. It was not generally necessary to use the poling boards on the lower one-fourth of the tunnel.

Line, grade and diameter were checked about every 6 feet. Any departure from line or grade was corrected by inserting washers between adjacent plate flanges until the lining was back on line and grade. In one case, where tunneling was started from two shafts, the two headings met within one-half inch of line and right on grade.

Excavation of the sand was a simple matter, most of it being readily pulled down and then shoveled into rubber-tired buggies. These buggies were pushed or pulled over a double plank runway to the elevator shaft, hoisted up and emptied into the hopper. These plank runways were decidedly more advantageous than an industrial railroad track would have been.

Brick Lining.—The black steel liner plates were intended only as a support until the brick lining could be laid. The bricks were laid longitudinally in three separate rings to give a total thickness of about 12 inches. Laying the invert or bottom half presented

no difficulties. For the crown or upper half, a simple semicircular template or form was built, held in place by means of trench jacks. As soon as a 4-foot length of crown had been built, the template was advanced again, the arching effect of the crown giving it sufficient strength to stand unsupported.

Engineering and Inspection.—The Engineering Department, under the direction of the writer, had charge of all lines, grades and inspection of workmanship and materials. Base lines were established at the base of each shaft by plumbing down on each side of the shaft, which established the base line at the bottom for a length of 12 to 13 feet.

The tunnel was driven both ways from the shafts. Points were established every 20 feet in the roof or top of the liner plates for line, and at each point a hook (or spads as they are called in coal mines) were fixed so that plumb bobs could be suspended from them and the center line easily located on the header. Grades 4 ft. above the finished flow line of the sewer were established every 20 feet, one on each side of the center line. By stretching cords between opposite points at two or more places, and sighting over the cords, a point 4 ft. above the finished flow line of the sewer was located wherever desired; and 13 in. below this was the lowest inside point of the liner plate.

Of three meetings of tunnel headings, the first missed 4 inches for line and 2 inches for grade; the second 2 inches for line and the grade checked; the third checked both ways; which record we consider very satisfactory.

Air and Lights.—Lights were placed every 25 to 30 feet throughout the entire length of the tunnel, the lines extending in both directions from the shafts. Both permanent and portable lights were established at all headers so that the workmen were always well supplied with lights. Air was forced into the tunnels through a 12-inch canvas tube suspended from the roof about 2 feet from the center line. This tube was carried to within 5 or 6 feet of the header and gave the men throughout the tunnel plenty of fresh air at all times.

Additional Tunneling.—The original plans of the Walnut Street sewer included a branch line of 24-inch and 18-inch vitrified pipe. This extension has been changed to a 42-inch inside diameter, 2-ring brick sewer, which will be extended to relieve a bad condition existing in the Seventh St. sewer. This will be 1770 ft. long and will be laid in tunnel owing to heavy traffic on the streets above. This tunnel will be about 25 to 30 feet deep and the lining will have a clear inside diameter of 60 inches. We may try using a shield over the top two-fifths of this tunnel instead of poling boards.

(Continued on page 65)



Laying brick inside liner plates in top half of sewer.



Buffalo's very complete chemical laboratory.

The Operation of Water Treatment Plants

Second Edition, Revised

Four years ago PUBLIC WORKS prepared and published the first complete text on this subject, designed for operators and superintendents everywhere, but especially in the smaller plants. In addition to the thousands of reprints issued by this magazine, many others have been made available through other channels. However, the demand continues, and to meet it, we are now issuing a revised and enlarged SECOND EDITION, in which have been incorporated some additional information and data on new developments.

The original manuscript was prepared by W. A. HARDENBERGH with the assistance and advice of a number of engineers.

In preparing this revised edition we have been assisted by the following: Henry N. Armbrust, Proportioneers, Inc.; A. N. Beck, Alabama State Board of Health; A. S. Behrman, Infilco, Inc.; L. K. Clark, Captain, U. S. Army; Jeff Corydon, Proportioneers, Inc.; F. C. Dugan, Kentucky Dept. of Health; A. E. Griffin, Wallace & Tiernan Co., Inc.; W. A. Helbig, Darco Corp.; J. K. Hoskins, Senior Sanitary Engineer, U. S. Public Health Service; David B. Lee, State Sanitary Engineer of Florida; R. J. Leveque, Phipps & Bird, Inc.; J. O. Logan, Mathieson Alkali Works, Inc.; J. J. McCarthy, Monsanto Chemical Co.; Wm. J. Scarlett, Wallace & Tiernan Co.; E. A. Sigworth, Industrial Chemical Sales Division; F. E. Stuart, Stuart-Brumley Corp.; F. M. Suarez, Philadelphia Quartz Co.; W. A. Taylor, W. A. Taylor & Co.; W. J. Van Reenen, American Norit Co., Inc.; W. H. Weir, Assoc. Director of Public Health Engineering, Georgia State Board of Health.

I. Introduction

1. Water purification is necessary primarily to eliminate or destroy those impurities that may affect health; a secondary and also important function is

the removal of those impurities, such as color, turbidity, taste or odor, that make the water undesirable to use. Actually there is a very close connection be-



Courtesy Hackensack Water Co.

Shoreline protection on Oradell Lake of the Hackensack Water Co., New Milford, N. J.

tween these two, in that the people of a community will not drink an unpalatable water; instead, they will use cistern, well or spring water which may be, and often is, unsafe. For this reason, the production of safe and satisfactory water involves the removal of (a) bacteria that may cause sickness; (b) color or turbidity that may be objectionable in appearance; (c) unpleasant tastes or odors; and (d) undesirable mineral content, hardness or acidity.

2. It is also good business policy to produce a water that meets the approval of a community. The income of the Water Department is dependent upon the use of water. If the water is turbid or hard, or contains certain other objectionable minerals in solution, it may be unfitted for industries, which will therefore develop their own supplies, instead of purchasing water from the city. In many cases, the quality of the water is the governing factor in the establishment of manufacturing plants. A good water is therefore an asset to a city.

3. For these and other reasons, no community should be satisfied to have a supply that is merely a safe one. The superintendent should exert every effort to provide water that meets with the fullest approval of health officials, consumers and industries. Fortunately, the science of water treatment has been so developed that this is possible for almost every community. New materials, methods and equipment are constantly being made available; by their intelligent and proper use a better quality of water can be produced. The object of this text is to provide basic information whereby every operator, no matter how small his plant, may improve his own knowledge and thereby better the service he renders.

II. How Impure Water May Cause Disease

1. *Diseases Spread by Water.*—Impure water may be the cause of spread of typhoid fever, dysentery and cholera, and also of certain variations of dysentery, as diarrhea, enteritis, etc. In the United States, typhoid and dysentery and their variations are quite common; cholera does not exist in sufficient amount to be a health menace, if at all.

2. *Method of Spread.*—All of these diseases are spread in the same manner. The bacteria causing them are discharged in the urine or feces of persons suffering from these diseases or by carriers. Carriers are persons who have suffered from one or more of

these diseases and have recovered, but continue to discharge the bacteria capable of carrying the disease to others.

The body wastes of such persons, if improperly disposed of, may reach the source of the water supply. Even when properly disposed of, as into a sewer system, cross-connections or leaking sewers may infect the water supply. Unless the methods of treatment remove or destroy these bacteria, the consumers are likely to contract disease.

For this reason, particular attention should be paid to the protection of the water supply against contamination or pollution; and unremitting care is necessary to insure the continuous safe treatment of the water.

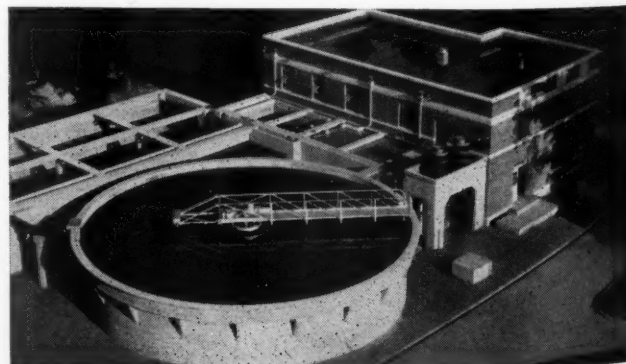
3. *Contamination and Pollution.*—The words "pollution" and "contamination" are often used interchangeably, but in this text they will be used as follows: *Contamination* refers to a condition where the quality of the water has been affected, but the appearance has not. *Pollution* affects appearance, and may affect quality also. For instance, the discharge of a small amount of sewage from a leaking cesspool might not affect the appearance of the water, but would make it unsafe to use through contamination. The discharge of wastes from a dye plant or a creamery would discolor the water and would be termed pollution.

For most water works, the problem of preventing these is a broad and important one. It covers the protection of watersheds to prevent the access of contaminating or polluting substances to the water supply; and also the protection of the water after it has been treated.

4. *Surface Supplies.*—The man in charge of a water works system should be familiar with the area from which the water supply is drawn. In a small supply, he should know personally every acre of the watershed. In a supply drawn from a large river, this detail knowledge is not possible, but collection of certain information is almost a necessity.

A map of the watershed should be maintained on which is spotted every source of actual or potential contamination or pollution, such as sewer systems, industrial plants, mines or other factors that may affect the quality of the water. Records should be maintained showing the kind of material discharged, the volume, variations, times of discharge and other pertinent information. If the effects on the water supply are known, adequate measures to remedy these can often be taken; or in cooperation with manufacturers measures may be adopted which will reduce the difficulties or the hazards due to such wastes.

In the small supply where the watershed area does



Lime is used in the St. Augustine, Fla., water softening plant. The Link-Belt Circuline sludge collector in foreground.

not exceed a few square miles in extent, a large scale map may show all existing or possible sources of contamination or pollution. Colored pins may be used to indicate the locations of contamination or the type of material discharged, or both. A sanitary survey of the watershed is, of course, one of the very first jobs to be done; in fact, before the area was selected as a source of supply, this should have been done in a painstaking manner and all danger areas carefully recorded. Thereafter, the area should be surveyed sufficiently often to know what the conditions are.

In most states there are adequate laws to protect water supplies. These provide that toilets, cesspools, etc., cannot be maintained near lakes and streams and if located on the watershed they must be of certain approved types of construction and must be properly maintained. Copies of regulations covering these points are available on request to your State Board of Health.

Hunting and fishing on watersheds are sometimes permitted. The desirability of doing this depends on local conditions. For the smaller communities, it is probably better to prohibit, so far as possible, all such uses of the water supply area; also skating. Where hunting and fishing are permitted, it should be by permit only. In very rare cases, if at all, is swimming permissible.

For detailed information on good practices in regard to the protection of watersheds and for data on permissible uses of watersheds for recreation, the reader is referred to the article by Capt. F. H. Whitely in *PUBLIC WORKS*, Aug., 1941.

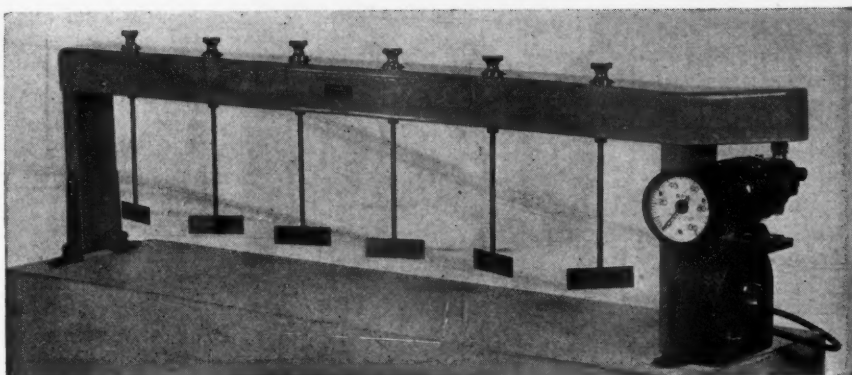
Storage reservoirs are not usually fenced, but distribution reservoirs should be covered. When fenced the bottom 2 feet of the fence should be of close mesh to prevent the entrance of frogs, newts or salamanders which may thus enter the distribution system and cause complaints from consumers.

5. *Springs and Wells*.—Springs should be protected from all surface wash by means of a tight concrete structure extending to rock, or for at least 6 to 10 feet into the ground and one foot or more above ground. It is preferable to cover the structure; or if not covered it should be protected by a fence as previously mentioned. Overflow pipes should be screened and so built that in times of flood or high water, surface water will not back up into the spring. These details should always be referred to the state sanitary engineer for advice and assistance, since local conditions may greatly influence needs.

The principal sources of danger in wells, aside from the quality of the water intentionally drawn from them, are leaky tops or casings. Poorly constructed tops may permit entrance of surface water; leaky casings, if near the ground surface, may also permit contaminated surface water to enter.

Wells should be protected against high water, so that floods will not affect them. Suction lines from wells to pumps should not be laid close to sewers or cesspools.

Most State Boards of Health have standard plans showing approved construction details for heads and casings for wells, which are available on request.



Phipps & Bird laboratory mixer.

III. Standards of Water Quality

1. *General*.—Certain standards based on experience and research have been established, by which to judge the quality of the water. For some types of impurities there can be no set standards that are desirable or practicable for all localities. Hardness, for instance, is judged by local conditions, and a water that would be considered hard in New England might be thought a soft water in North Dakota. But for those impurities that affect health, there are and should be strict standards that apply in all places.

The United States Treasury Department has formulated a set of standards which have been quite generally adopted. Essentially these require that:

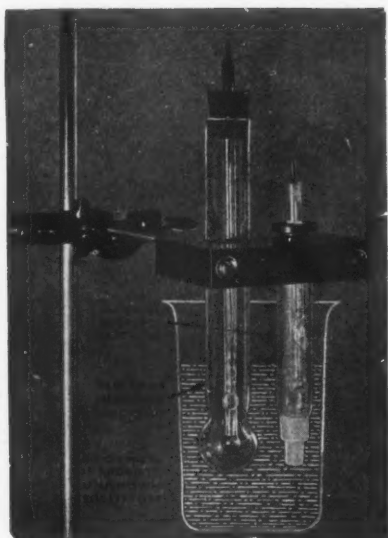
The water must be obtained from a source free from contamination or pollution or adequately protected against them. The water supply system must be free from sanitary defects, in wells, reservoirs, treatment plants, distributing systems, etc.

In regard to bacterial quality, rigid restrictions are placed on the presence of coliform bacteria, that is bacteria of the colon types, which are so commonly found in sewage that their presence in water is assumed to indicate sewage contamination. Physically, the water must be clear, colorless and odorless, pleasant to the taste, and without any excessive amount of dissolved minerals. The common standards in regard to most of these are given here and in connection with the outline of tests hereafter; in others, no fixed limits are applied, because acceptable and usual standards vary in the different parts of the country. Treasury Department standards are now being revised, but material changes in them are unlikely. Reprint 1029, Public Health Reports, which contained the original standards is not now available. Herewith is a summary showing the permissible limits of various chemicals in parts per million:

Chemical	Limit Not More Than (P.P.M.)	
	Old Standard	Proposed New Standard
Lead (Pb)	0.1	0.1
Copper (Cu)	0.2	2.0
Zinc (Zn)	5.0	15.0
Iron (Fe)	0.3	0.3
Sulphate (SO ₄)	250.	250.
Magnesium (Mg)	100.	125.
Chlorides (Cl)	250.	250.
Total Solids	1000	800.

IV. Methods and Units of Measurement

1. *General*.—In water treatment plant operation, including the performance of tests and the use of chemicals, several methods of measurement are employed. The metric system is utilized generally in



A simple form of electrode for measuring pH. (L. & N.)

laboratory work, while, in treatment, dosages are computed in one or more of three ways: Grains per gallon (gpg); parts per million (ppm.) and pounds per million gallons (lbs./mg.). The operator should be familiar with all of these. He should also be familiar with the metric system. In using the metric system, it is often necessary to transpose such units as grains or

milligrams to ounces or pounds, or liters or milliliters to gallons or cubic feet.

2. The Metric System.—In making tests, the units of the metric system are often or ordinarily employed, and the operator must be familiar with these.

In the metric system, the standard unit of volume is the liter (slightly more than 1 quart). This weighs 1 kilogram (kg) and is equal in volume to 1,000 cubic centimeters (abbreviated c.c.); and also to 1,000 milliliters (ml.), which unit is now generally used instead of the cubic centimeter. Both of these have the same value for all practical purposes.

The standard unit of weight is the gram, which is the weight of 1 c.c. or 1 ml. of water. One gram contains 1,000 milligrams (mg.). It is convenient to remember that 1 mg. per liter equals 1 part per million (ppm.).

To summarize:

1 liter = 1,000 c.c. = 1,000 ml.

1 kilogram = 1,000 grams = 1,000,000 mg.

3. The Centigrade Scale.—The centigrade scale of measuring temperatures is used commonly in laboratory work in preference to the Fahrenheit scale commonly employed in this country. In the centigrade (C) scale, freezing is at 0° and boiling at 100°; in the Fahrenheit (F) scale, freezing is at 32° and boiling 212°.

To change F to C: Subtract 32 from the F reading, divide the remainder by 9 and multiply this answer by 5. Example: 95° F. Subtract 32 leaving 63; divide by 9 equals 7; $5 \times 7 = 35^\circ$ C. Ans. To change to F.: Divide by 5, multiply by 9; add 32. Example: 20° C. Divide by 5 equals 4; $4 \times 9 = 36$; $36 + 32 = 68^\circ$ F. Ans.

4. Measuring Amounts of Chemicals.—As already stated, there are three common methods of measuring the amount of chemicals in water. These are: grains per gallon (gpg); parts per million (ppm.); and pounds per million gallons.

Since there are 7,000 grains in an avoirdupois pound, 1 grain per gallon equals 1 pound in 7,000 gallons or $1,000,000 \div 7,000 = 142.9$ pounds per million gallons. A gallon of water weighs 8 1/3 pounds; therefore 1 gpg = $142.9 \div 8 \frac{1}{3} = 17.1$ ppm. Thus 1 gpg = 17.1 ppm. = 142.9 pounds per m.g.

1 ppm. = .058 gpg = 8.34 pounds per m.g.

1 pound per m.g. = .007 gpg = 0.12 ppm.

When Imperial or Canadian gallons are used, these figures change. The U. S. gallon equals 0.83 Imperial gallon. One grain per Imperial gallon equals 14.2 ppm. or 119 pounds per million Imperial gallons.

5. Laboratory Equipment.—A laboratory and laboratory equipment are required for every plant. It is not necessary that the laboratory be large, nor the equipment costly. What is needed depends upon the tests that are to be performed, and these, in turn, depend upon local conditions. A laboratory layout for a small plant and a list of the equipment needed to make the various tests can be obtained from your State Board of Health by addressing the State Sanitary Engineer, or will be furnished by the Editor of this magazine without charge. *Standard Methods of Water Analyses* can be obtained from the American Public Health Association. Orders will be forwarded to the publishers of this book by the Editor of this magazine. Other books of value for laboratory use and guidance are: *Analysis of Water and Sewage*, by Theroux, Eldridge and Mallman; and *Operation of Water Treatment Plants* by Hardenbergh. Both of these texts outline the procedures for making the tests in a simplified form and will be found to be of special value to those who have not completed a formal course in laboratory procedures.

V. Procedures in Testing

1. Standard Methods and the other texts just mentioned should be followed in detail. Some of the tests are presented hereafter in a somewhat simplified form, including the tests for turbidity, color, odor, pH, alkalinity and acidity, carbon dioxide, hardness, and residual chlorine, and the procedure in certain microscopical examinations. Procedure in bacterial examination will be discussed, but it is recommended that the details and technique of these examinations be learned through attendance at short schools or other courses of instruction that are provided in almost every state. Other tests of a similar nature, as those for dissolved oxygen, chlorides, nitrates and nitrites, etc., also should be learned by actual instruction and practice.

2. Taking Samples for Physical and Chemical Tests.—From 2 to 4 quarts of water (2 liters or more) are required for the usual physical and chemical tests. The water should be collected in glass bottles equipped with glass stoppers. Bottles should be cleaned before use by dipping in either alkaline permanganate solution or dilute sulphuric acid and potassium dichromate; they are then dipped in a weak mixture of oxalic and sulphuric acids; and then rinsed with water and allowed to drain. The sulphuric acid-potassium dichromate solution is prepared as follows: Add 120 grains of potassium (or sodium) dichromate to 1500 c.c. of tap water and dissolve with the aid of heat. Then add 180 c.c. of commercial sulphuric acid.

A representative sample of the water must be obtained to represent truly the condition of the water. When taking a sample from a stream or lake, the bottle is placed about 18 inches below the surface in order to avoid the surface film. The stopper is then removed, the bottle allowed to fill and the stopper replaced. When taking a sample from a faucet that has been closed, or from a similar source, allow the water to run to waste for a few minutes. If the sample is taken from a pump that is not in operation at the time, sufficient water should be wasted to empty all of the pump connections, or if the pump is started it should be run long enough to draw water from the

well, main or other source. Containers should be filled completely.

Tests should be made promptly after the sample has been collected. According to *Standard Methods*, examinations may be made on unpolluted water within 72 hours, on fairly pure water within 48 hours and on polluted water within 12 hours. These are maximum limits; shorter elapsed periods are desirable.

(a) Turbidity

(1) *General*.—Particles of soil carried in suspension in the water cause a muddy or turbid appearance. Such water is objectionable for general consumption and must be treated before use, though turbidity alone does not affect health.

The amount of turbidity in water before treatment is important in determining dosages of chemicals for coagulation. There should be almost no turbidity in water that has been filtered; proper treatment will remove practically all turbidity.

(2) *Permissible Limits*.—The upper limit of turbidity that will not cause some complaints from consumers is about 5 ppm.; that is, five part by weight of solid matter to a million parts of water, but a turbidity of 10 is generally considered permissible.

(3) *Method of Determining Turbidity*.—Three methods of testing the amount of turbidity are available. These are (1) by means of the turbidity rod of the U. S. Geological Survey. (2) by means of the candle or Baylis turbidimeters and (3) by comparison with previously prepared standards. The turbidity rod is used mainly for field determinations; the turbidimeters for laboratory work.

The turbidity rod is about 4 feet long. At the lower end a bright platinum needle or wire 1 inch long and one millimeter (1/25 inch) in diameter projects at right angles to the rod. At the upper end, 1.2 meters (47 1/4 inches) above the needle is a ring. The lower end of the rod carrying the platinum wire is submerged vertically into the water, the eye being held at the ring. The rod is graduated to show turbidity. When the wire just disappears from view in the water the surface of the water marks on the rod scale the turbidity reading. A turbidity that causes the wire to disappear with a submergence indicated in the scale by 70, has a turbidity of 70, and will be of decidedly muddy appearance. With a turbidity of 70, the wire can be seen when it is not more than about 5 1/8 inches below the surface, with a turbidity of 30, the wire can be seen at a depth of about 11 2/3 inches.

A homemade turbidity rod may be constructed as follows: Take a straight piece of hardwood about 4 1/2 ft. long and 1 or 1 1/4 ins. square and near one end fix firmly a bright pin. At a distance of 47 1/4 inches from the pin fix a sighting ring. Stain the wood a light brown, and graduate the rod exactly as indicated below:

Distance from Pin in Inches	Turbidity Reading
0.82	1000
1.22	500
1.70	300
2.26	200
2.83	150
3.94	100
5.12	75
7.36	50
11.65	30
16.77	20
21.69	15
31.26	10

by which
Fahrenheit and
Centi-
temperatures
be read di-
rectly.

This rod is used in the same manner as the standard rod described above.

The reading should be taken in the open, preferably when the light is good as in the middle of the day, but not in direct sunlight.

The candle turbidimeter consists of a graduated tube so placed in a holder that it is held over a standard candle or electric light, while light is excluded from the sides. Turbidity is determined by pouring the water into the tube until the flame of the candle just disappears from view. The graduations on the tube then indicate the turbidity. After the image of the candle flame has disappeared, removal of 1% of the liquid in the tube should make it visible again. Observations should be made in a darkened room or with a black cloth over the head.

The tube should be kept clean, inside and out, soot from the candle on the bottom of the tube must be removed. The flame of the standard candle tends to increase in size after a few minutes burning, thus causing error. Before lighting, the charred part of the wick should be removed; during the test, the flame must be kept a constant distance below the bottom of the tube.

The candle turbidimeter cannot be used to read turbidities below about 25. For water with lower turbidities, it is better to obtain results by the Baylis turbidimeter or by comparison with standards.

For preparing standards for determining turbidity by means of comparisons, Fuller's earth is used. Equipment required includes a 200-mesh sieve, a small amount of Fuller's earth, and 10 or 12 250 ml. bottles. Sift enough Fuller's earth to produce at least 1 gram. Add exactly 1 gram to exactly 1 liter of distilled water; and mix. The resulting turbidity is 1,000, that is, 1,000 parts per million. This is called *standard suspension*. Its turbidity should be checked with the turbidimeter and adjusted if in error which it should not be if the work is done carefully.

On each of the bottles place labels, to indicate turbidity, as 5, 10, 20, 30, 40, 50, etc. Prepare as shown in the table below by placing in each 250 ml. bottle, a portion of the standard suspension, and filling with distilled water.

Bottle Marking ppm. of Turbidity	Add of Standard Suspension	Add Dist. Water to Fill
5	1.25 ml.	248.75 ml.
10	2.50 ml.	247.50 ml.
20	5.00 ml.	245.00 ml.
30	7.50 ml.	242.50 ml.
40	10.00 ml.	240.00 ml.
50	12.50 ml.	237.50 ml.
Etc.		

The pipette or graduate used to handle the standard suspension should be rinsed carefully and excess water shaken out before each portion is measured. The standard suspension solution should be shaken before each portion is withdrawn. As many standards as are desired may be prepared.

Place the water whose turbidity is to be determined in a similar 250 ml. bottle and compare with the standards. A background of ruled lines of various widths is a help in comparing.

(4) *Expression of Results*.—According to standard practice, results are recorded as follows:

Turbidity between 0 and	1 to nearest	0.1
1 and	50 to nearest	1
51 and	100 to nearest	5
101 and	500 to nearest	10
501 and	1000 to nearest	50
1001 and greater	to nearest	100

In reporting, therefore, a turbidity of 33 should be

reported as 33; a reading of 53 should be reported as 55, and 62 should be reported as 60; a turbidity of 106 should be reported as 110, and one of 518, as 500.

(5) *Removal of Turbidity*.—Turbidity is removed by coagulation and filtration, which methods will be described in Section VI and VII.

(b) Color

(1) *General*.—Color in water is due to material that is in solution in the water, as from decaying organic matter in swamps, where it consists of the tannates, gallates and organic acids from leaves and bark, and from plants. An apparent color is sometimes caused by colored matter in suspension, but true color is in solution.

(2) *Permissible Limits*.—Color is an objectionable, though ordinarily harmless, quality and to avoid complaints from consumers water should not contain more than 10 parts per million of color.

(3) *Determination of Color*.—This test is a simple one. A standard 50 c.c. Nessler tube may be used. This is filled and compared with a series of color standards. The tubes are viewed by placing them on a white surface and looking down on them from above.

Color solutions for comparisons may be made by dissolving potassium chloroplatinate and cobaltous chloride in distilled water, but it is simpler to purchase the standards, either in solution form, or as colored glass discs.

When there is suspended matter in the water, it is impossible to determine the real color, and removal of such matter must precede the color test. Filtering out of the suspended matter produces a decolorizing action; removal of the suspended matter by centrifuging is best. For details of procedure refer to the texts already listed.

(c) Taste and Odor

(1) *General*.—Tastes and odors usually occur together. They may be caused by volatile oils produced in the growth or decomposition of algae, including diatoms, in the water; by the decomposition of vegetable matters; by dissolved gases; by the presence of industrial wastes, etc. See also Section XII on Taste and Odor Control.

(2) *Determination of odor* may be made with the water either hot or cold—the former giving the more positive results. The intensity and quality or kind of odor is, of course, largely a matter of personal opinion, but trained “smellers” will often agree quite closely. There has been much recent research and development in this field. The data below are based on the eighth edition of Standard Methods. In appendix A are given other data.

Cold odor is determined by filling a bottle or flask (capacity about 300 to 500 ml.) half or two-thirds full, with water at room temperature (20° C.), shaking violently, removing the stopper and smelling.

Hot odor is determined by heating about 200 ml. of water in a 500 ml. flask, the neck being covered with a watch glass; bring to 65° C., remove flask from the heater, agitate with a rotary movement, slip the watch glass cover to one side and smell.

The “Threshold Odor” test is commonly used as the best available method of determining in-

tensity of odor. If an odor is detected in the sample, add 200 ml. of odor free water to 200 ml. of the sample, thus diluting it to 1 in 2. This procedure is repeated, with the next dilution representing 1 in 4, the next 1 in 8, etc., until a second dilution is reached below which odor is not readily detectable. Then starting with the sample of greatest dilution, test the samples in order until one is reached in which odor is just detectable. This is the threshold odor and is recorded as the odor concentration.

Expression of Odor Quantity

Number of Successive Dilutions	Odor Intensity	Odor Concentration
No odor in undiluted sample	None	(0)
0	0	1
1	1	2
2	2	4
3	3	8
4	4	16
Etc.	Etc.	Etc.

If hot odor tests are made, separate dilutions are necessary. Odor characteristics are listed in *Standard Methods*, which should be consulted for details of the above test.

(d) Mineral Constituents of Water

(1) *General*.—Alkalinity, hardness, acidity and salinity occur in water due to the presence of certain soluble materials. These qualities are measured by means of several tests which, in some cases, are nearly enough related to each other to cause confusion. A particular example is the broad use of the term “alkalinity,” which is employed as the opposite of “acidity” in connection with pH or hydrogen ion tests; and is also used to designate the amount of certain dissolved minerals that the water contains—the bicarbonates, carbonates and hydroxides of calcium, magnesium, sodium and potassium; the hydroxide, however, is found only in treated water, not in natural waters. There is, of course, no relation between a pH of 8.0 and an alkalinity of 8; the pH reading of 8.0 indicates that the water is quite alkaline, whereas an alkalinity of 8 indicates that the water contains 8 ppm. of some or all of the minerals mentioned above. In this article, *pH* refers to the *intensity* of alkalinity or acidity and *alkalinity* refers to the *amount* of carbonates, bicarbonates or hydroxides that are present.

(2) *Causes of Alkalinity*.—The compounds in natural water that causes only alkalinity are potassium carbonate (K_2CO_3) and bicarbonate ($KHCO_3$) and sodium carbonate (Na_2CO_3) and bicarbonate ($NaHCO_3$). The following compounds cause both alkalinity and hardness: Calcium carbonate ($CaCO_3$) and bicarbonate ($Ca(HCO_3)_2$), and magnesium carbonate ($MgCO_3$) and bicarbonate ($Mg(HCO_3)_2$).

(3) *Causes of Hardness*.—The following compounds cause hardness: The calcium and magnesium carbonates and bicarbonates; this is known as carbonate hardness and is sometimes called temporary hardness because some of it can be removed by boiling. The following compounds cause non-carbonate (sometimes called permanent) hardness and also salinity; calcium sulphate ($CaSO_4$) and chloride $CaCl_2$ and magnesium sulphate ($MgSO_4$) and chloride ($MgCl_2$).

(4) *Causes of Salinity*.—In addition to the calcium and magnesium sulphates and chlorides, salinity is caused by potassium sulphate (K_2SO_4), chloride (KCl) and nitrate (KNO_3), and by sodium sulphate (Na_2SO_4), chloride ($NaCl$) and nitrate ($NaNO_3$).



Imhoff Cone, essential in making tests for settleable solids.

(5) *Causes of Acidity.*—Acidity in water is caused by free carbon dioxide (CO_2), by various mineral acids, by iron and aluminum sulphates and by other less common compounds.

(6) *Equipment for Tests.*—Determination of alkalinity and acidity is simple. Necessary equipment includes a burette (50 c.c. capacity, with 1/10 c.c. graduations, and a stop cock); a burette support; a 100 c.c. cylinder; 6 Erlenmeyer flasks; indicators and the acid solution for determining alkalinity. This equipment will cost about \$10, and is all that is necessary for determining alkalinity. For determining acidity, additional equipment will cost about \$3, unless it is desired to have a somewhat more elaborate burette. A very good set can be purchased, that will be suitable for all these tests, for about \$15.

In addition, a pH comparator and a copy of *Standard Methods of Water and Sewage Analyses* should be available. The cost for the pH set depends somewhat on the type selected. For \$35 to \$50 it is possible to purchase the pH set, *Standard Methods*, and all of the equipment listed above.

(e) Alkalinity

(1) *General Determination.*—The amount of alkalinity is determined by adding a standard acid in measured quantity; the acidity is determined by adding a standard alkali. The amount of acid or alkali required to neutralize the sample indicates the amount of alkalinity or acidity.

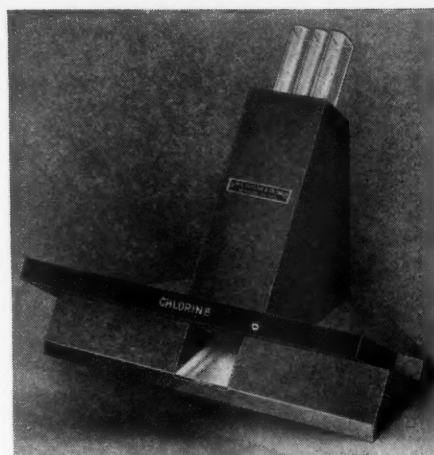
(2) *pH Determination.*—The measurement of the intensity of alkalinity or acidity, that is, the hydrogen ion concentration or pH, is best performed by using an electrical pH indicator, but is more commonly made by using one of the several colorimetric pH comparators. With these, a small amount of the water to be tested is placed in a tube—from 5 to 15 c.c.—and the color reagent is added. The color is then compared with glass or liquid standards. Thus pH determinations are extremely simple.

The pH scale ranges from 1 to 14; 7 is neutral. Values below 7.0 indicate acid water; above 7.0 alkaline waters. The degree of intensity of acidity increases as the numbers become smaller: Thus 6.6 is acid, 5.8 more acid, 3.5 still more acid. The degree of intensity of alkalinity increases as the pH numbers increase: Thus 7.6 is alkaline, 8.5 more alkaline and 10.1 even more alkaline. In general, pH is determined to one decimal point, as 5.6, 7.4, 8.2 or 9.3.

This determination of the intensity of alkalinity does not give any indication of the *amount* of alkalinity that must be neutralized, except in conjunction with other tests.

(3) *Amount of Alkalinity.*—To test a sample for alkalinity by means of color indicators, 100 c.c. (or ml.) of the sample is placed in the Erlenmeyer flask and four drops of the phenolphthalein indicator are added. Phenolphthalein alkalinity measures all of the hydroxides and half of the carbonates. The flask is shaken. If a pink or red color appears, the water is alkaline to phenolphthalein. If no color appears, the water contains no carbonate or hydroxide alkalinity. If there is a color reaction, add the standard N/50 sulphuric acid solution drop by drop, shaking the flask after each addition, until the color just disappears. The number of c.c. (or ml.) of acid solution used must be noted. The alkalinity to phenolphthalein is 10 times the number of c.c. (or ml.) required to cause the color to disappear. If 3.7 ml. were required, the alkalinity to phenolphthalein is $10 \times 3.7 = 37$ ppm.

The sample already used for the phenolphthalein



Taylor water analyzer.

test is ordinarily used for the methyl orange alkalinity test; or a new sample of 100 c.c. can be used. Methyl orange measures the total alkalinity. To the sample is added 2 drops of the methyl orange indicator. If the solution becomes yellow, there is hydroxide, normal carbonate or bicarbonate present. The N/50 solution of sulphuric acid is added as before until the yellow color just begins to turn to orange. The alkalinity to methyl orange in parts per million is equal to 10 times the number of c.c. (or ml.) of sulphuric acid solution necessary to cause the color change. If a fresh sample has been used, and 5.8 c.c. are required, the alkalinity to methyl orange is 58 ppm. Methyl orange alkalinity includes also the phenolphthalein alkalinity; hence if the sample previously used for phenolphthalein is used for the methyl orange test, the total amount of acid in both tests is used for computing.

If the water is turbid or colored, erythrosine should be used instead of methyl orange. Results are the same, but with this indicator the color change is shown by the drops of chloroform added, and not by the water.

Procedure is as follows: To 100 c.c. of the water to be tested, add 5 c.c. of neutral chloroform and 1 c.c. of erythrosine indicator. If the water is alkaline, the drops of chloroform will be pink; if acid, the drops will show no color. Add standard N/50 acid solution, as for methyl orange, if alkalinity is present, shaking vigorously until the color of the drops change from pink to colorless. Multiply the number of c.c. of N/50 acid solution required by 10 to determine the alkalinity of the water.

References hereafter made to methyl orange alkalinity apply equally to erythrosine alkalinity.

(4) *Types of Alkalinity.*—From the results of these tests, a great deal of information can be obtained regarding the mineral content of the water. But it is desirable first to mention the three types of alkalinity. These are bicarbonate alkalinity, which exists in the range below pH 8.3; the carbonate alkalinity with no CO_2 present which exists in the range above pH 8.3; and the caustic or hydroxide alkalinity, found above pH 9.4, in which no bicarbonates and no CO_2 are present, and which may thus overlap the carbonate alkalinity.

The phenolphthalein and methyl orange tests are based on the facts that phenolphthalein is colorless when CO_2 is present, but shows a pink color when this gas is removed, which occurs at about pH 8.3; and that methyl orange is orange in the presence of strong acids, but turns to yellow when the acidity is

less—above about pH 4.4. In the latter case, the acid solution, as it is added, neutralizes the alkaline bicarbonates in the water; and after these are neutralized, a very small additional amount of acid causes the pH to shift to about 4.4 and the yellow color of the indicator then turns to orange; if still more acid is added, the orange changes to pink.

(5) *Determination of Types of Alkalinity.*—If the alkalinity to phenolphthalein is 0, that is, there is no color reaction to the addition of the phenolphthalein indicator solution, there is no caustic alkalinity and no carbonate alkalinity, but the alkalinity to methyl orange as shown by the test represents the bicarbonate alkalinity.

Example: Alkalinity to phenolphthalein is 0.0 ppm.; and to methyl orange is 18.5 ppm. Therefore, caustic alkalinity is 0; carbonate alkalinity is 0; and bicarbonate alkalinity is 18.5.

When the alkalinity to phenolphthalein is less than one-half the alkalinity to methyl orange, there is no caustic alkalinity; the carbonate alkalinity is twice the phenolphthalein alkalinity; and the bicarbonate alkalinity is the methyl orange alkalinity minus twice the phenolphthalein alkalinity.

Example: Alkalinity to phenolphthalein is 28.0 ppm.; and to methyl orange 86.0 ppm. Therefore, caustic alkalinity is 0; carbonate alkalinity is 56.0 ppm.; and bicarbonate alkalinity is $86 - (2 \times 28) = 30.0$ ppm.

When the phenolphthalein alkalinity is exactly one-half of the methyl orange alkalinity, the caustic alkalinity is 0, the carbonate alkalinity is the same as the methyl orange alkalinity, and the bicarbonate alkalinity is 0.

Example: Phenolphthalein alkalinity is 72.0 ppm. and methyl orange alkalinity is 144.0 ppm. Therefore, the caustic alkalinity is 0.0 ppm.; the carbonate alkalinity is 144.0 ppm.; and the bicarbonate alkalinity is 0.0 ppm.

When the phenolphthalein alkalinity is more than one-half of the methyl orange alkalinity, caustic alkalinity is twice the phenolphthalein alkalinity minus the methyl orange alkalinity; the carbonate alkalinity is twice the difference between the phenolphthalein and methyl orange alkalinities; and the bicarbonate alkalinity is 0.

Example: The phenolphthalein alkalinity is 150 ppm.; the methyl orange alkalinity is 196 ppm. Therefore, the caustic alkalinity is $2 \times 150 - 196 = 104$ ppm.; the carbonate alkalinity is $(196 - 150) \times 2 = 92$ ppm.; bicarbonate alkalinity is 0.

When the phenolphthalein and methyl alkalinities are the same, all the alkalinity is caustic alkalinity and carbonate and bicarbonate alkalinities are 0.

The alkalinity in natural waters is almost always bicarbonate alkalinity, though occasionally some carbonate is present in addition to the bicarbonate. Caustic alkalinity is found only in treated waters—most commonly in lime-softened waters.

(f) CO₂ Determination

(1) *Determination.*—To determine the free CO₂ content of the water, the same apparatus is required as for determining alkalinity; also the phenolphthalein indicator; and a solution of N/44 (or N/50) sodium hydroxide, which can be purchased ready for use.

To 100 c.c. of the sample, 10 drops of the phenolphthalein indicator are added, and then the sodium hydroxide solution, drop by drop, shaking the sample meanwhile, until a faint pink color is produced. The free CO₂ in parts per million equals 10 times the num-

ber of c.c. of the N/44 sodium hydroxide solution used. If an N/50 solution is used, the multiplier is 8.8.

The total acidity is obtained by adding 4 drops of the phenolphthalein indicator to 100 c.c. of the water which has been placed in a white dish or in a flask on a white surface. The N/44 sodium hydroxide solution is then added until a pink color is obtained. The total acidity in parts per million of calcium carbonate equals 11.4 times the c.c. of sodium hydroxide used. If an N/50 solution is used instead of the N/44, the multiplier is 10 instead of 11.4.

Acidity is reported as the parts per million of calcium carbonate.

(g) Hardness

(1) *General.*—As already stated, calcium and magnesium compounds cause hardness. Formerly hardness was classified as temporary (which can be removed by boiling) and permanent (which cannot be removed by boiling). These classifications are best replaced by the terms carbonate and non-carbonate hardness, a reason being that, in the usual methods of softening by the addition of lime, soda ash, etc., treatment is based on these characteristics.

Carbonate hardness is caused by the presence of calcium and magnesium bicarbonates. Non-carbonate hardness is caused by calcium and magnesium sulphates and chlorides.

(2) *Determining Hardness.*—For an accurate determination of hardness it is necessary to determine the amounts of calcium and magnesium in the sample, which requires a lengthy chemical procedure. Training in this is available at various of the Short Schools conducted by many State Boards of Health. At least one device is on the market for measuring the hardness. For approximate measurement of the hardness, the soap test can be used, though what this actually measures is the soap destroying power of the water.

(3) *Procedure.*—A burette for measuring small quantities, a 250 c.c. glass stoppered bottle and a quantity of standard soap solution are required. The burette used in alkalinity and acidity determinations may be used, if properly washed. Standard N/50 soap solution may be purchased ready for use. Test the lather factor by placing 50 c.c. of recently boiled and cooled distilled water in the bottle, and adding soap solution 0.1 ml. at a time, and shaking. Continue until a lather forms that will remain unbroken for 5 minutes. This usually requires 0.5 to 1.5 ml. of soap solution. Note this as the lather factor.

Place 50 ml. of the water to be tested in a similar bottle and add the soap solution 0.2 or 0.3 ml. at a time, shaking vigorously and noting the lather formed. As soon as the lather breaks, add more soap solution; and shake again. When a lather forms, and remains unbroken for 5 minutes, note the reading on the burette and note the amount of soap solution used. After 5 minutes, add 0.5 ml. of soap solution and shake. If a 5-minute lather does not then appear, the first result was a false end-point due to the presence of magnesium, and the addition of soap solution and shaking should continue until a true lather is formed.

From the ml. of soap solution used, subtract the amount of soap required to form the lather factor and multiply the remainder by 20 to obtain the hardness by the soap method.

(h) Residual Chlorine

(1) *General.*—After a water has been chlorinated, the presence of residual chlorine can be determined

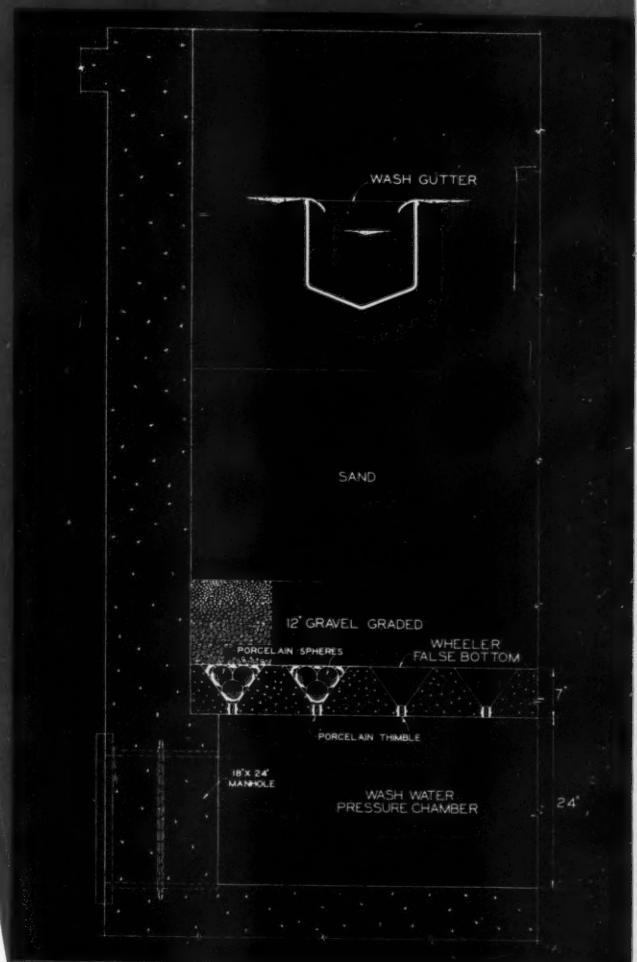
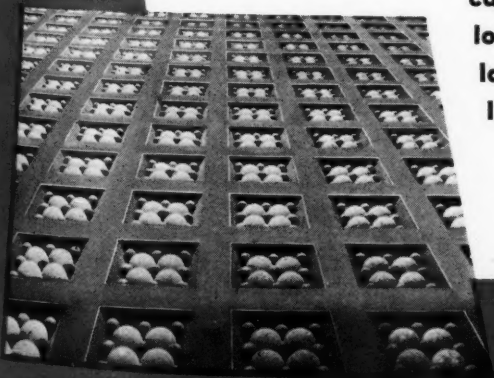
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by the orthotolidine or the starch iodide tests. The former enables the operator to determine *how much* chlorine remains in the water; the latter indicates only that chlorine is present. The former is therefore generally more valuable and is more widely used.

(2) *Procedure with Orthotolidine.*—A standard orthotolidine solution is furnished by makers of chlorinating apparatus and by laboratory and chemical supply houses. Using a Nessler tube 300 mm deep, fill with the water to be tested, allow to stand 10 minutes, and add 1 c.c. of orthotolidine solution. Shake, and allow the mixture to stand 5 minutes; the resulting color, if any, indicates the amount of residual chlorine in the water. A very light yellowish color indicates about 0.1 ppm., and the color deepens with the increase of chlorine. Color standards are therefore necessary in order to read closely the amount of chlorine present. It is best to use one of the several excellent chlorine comparators, as these permit quick and accurate readings. Directions for use are supplied by the manufacturers.

When ammonia and chlorine are used in the treatment of the water, or when iron or manganese are present in sufficient quantity to interfere with the test, modifications are necessary in the procedure.

(3) *With Ammonia-Chlorine.*—When both ammonia and chlorine are applied to the water, a longer period is necessary for the color to develop after the orthotolidine has been added. Instead of the 5 minutes when chlorine alone has been applied, a 10 to 30 minute period is necessary.

(4) *With Iron and Manganese.*—If either of these minerals is present, a false color reaction occurs with orthotolidine, thus making the test for residual chlorine unreliable.

Since residual chlorine rarely persists for as much as 24 hours, two samples may be collected each day, one of which is tested at once and the other allowed to stand for 24 hours. When the two samples have been collected on the succeeding day, a test is run on one of these and also on the sample held over from the preceding day. Thus two tests are made each day—one on a sample just collected, the other on a sample held over from the preceding day. The apparent chlorine content of the latter is subtracted from the apparent chlorine content of the former to secure the approximate true residual.

Another method is to collect two samples; test one, and boil the other until about 25% of it is boiled off. Bring up to the original volume with distilled water, cool, test and subtract the apparent residual chlorine content of the boiled sample from the first sample. The boiling drives off the residual chlorine; also, it sometimes affects the iron and manganese compounds, so that strictly accurate results are not obtained, but the errors are not usually great enough to be important.

(5) *Starch Iodide.*—By this test, the presence of chlorine in the water is indicated by a faint blue color. The reaction takes place with a chlorine residual of 0.10 to 0.15 ppm. and is therefore adequate to indicate a satisfactory residual. A rather deeper color is obtained with higher chlorine residuals, but the test is not really a quantitative one.

A starch solution is purchased or made up in accordance with directions in *Standard Methods*; in addition to this, some crystals of potassium iodide (the powdered form may be used), and a Nessler tube, bottle, or test tube are needed.

After the sample to be tested has stood for 10 minutes, add 2 or more crystals of potassium iodide, and

10 to 20 drops of starch solution. Shake, hold over a white surface and look down through the sample. A blue color appearing within 5 minutes indicates the presence of chlorine. Color obtained after the 5-minute period should be disregarded. A dark blue indicates that the chlorine dosage is probably unnecessarily large. No color indicates that the chlorine dosage should be increased.

(i) Bacterial Examination

(1) *General.*—Bacteria are such very small organisms that a special unit of length has been devised to measure them. This is the micron which is .001 millimeter or about 1/25,000 inch long. One method of classifying bacteria is by shape. Under this method there are three general types: *Cocci*, which are round or spherical; *Bacilli*, which are rod-shaped, like a cigar; and *Spirilla*, which are spiral, like a corkscrew. Bacteria normally found in water supplies are of the Bacilli group, and are from 1 to 4 microns long and about 1/4 as thick. Because of their very small size, special methods are necessary in order to find and identify them.

For the water works operator or superintendent or sanitary engineer, concerned primarily with preventing water-borne disease, there are two broad classifications—*pathogenic*, that is disease bearing or disease producing; and *non-pathogenic*, which do not produce, cause or convey disease.

Non-pathogenic bacteria cannot be ignored entirely, because the presence of certain of these is often strongly indicative of the possibility that disease bearing bacteria also are present. For instance, typhoid bacteria (*E. Typhosus*) are very difficult to find in water, milk, etc., even when present, so that the usual method of procedure is to test for the coli-aerogenes group, which are constantly present in the human intestines and in urine and feces. If such bacilli are found it is practical proof that the water or milk is contaminated with sewage; and if sewage contamination is present, it is only a matter of time before typhoid bacilli will appear and cause disease. The coli-aerogenes group, however, no not cause disease.

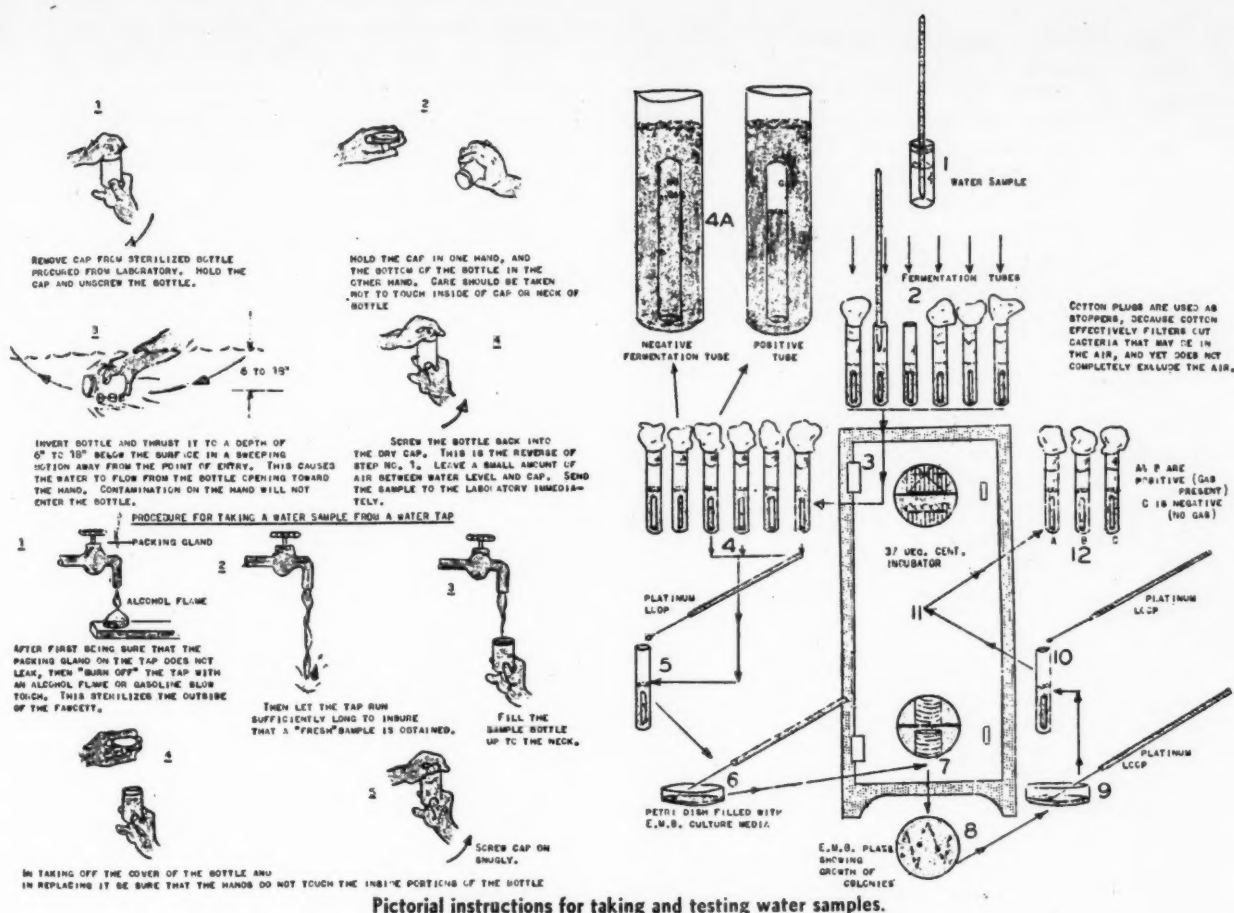
It is for these reasons that reports of bacterial examinations of water show the results of tests for coli, and if these are present the water is condemned as bad, even though no examination has been made for *B. typhosi*.

Bacteria multiply very rapidly by dividing so that a single bacterium, under favorable conditions, will produce many thousand others in the course of 24 hours. Temperature is important; for those organisms, such as coli and typhosi, which live in the body, body temperatures are most favorable, that is, around 98° F or 37° C, but multiplication takes place even at much lower temperature. A temperature of about 135° F kills most of these bacteria, but does not affect certain other forms of less importance to public health.

While low temperatures are unfavorable to bacteria, even freezing will not kill all of them, and typhoid bacteria have survived for months in ice. Therefore the use of ice from contaminated water is dangerous.

(2) *Bacterial Examinations.*—There are three important steps in examining water for bacteria: These are: (1) Collection of the sample; (2) determining the total number of bacteria; (3) determining the presence and total number of the coli-aerogenes group.

Samples must be collected in a clean, sterile, glass-stoppered bottle, from 4 to 8 ounces in capacity. Laboratories will furnish such bottles. Samples collected in other types of containers are valueless. When taking a sample from a faucet (which should be flamed),



the water should be allowed to run until water is drawn from the main. When drawing from a pump, or hydrant, the sample should be taken only after water from the main, well or reservoir is being drawn. In the case of a lake or stream the stopper is removed, the bottle placed beneath the surface and filled with a sweeping motion so water touching the hand will not enter the bottle.

Immediately after filling, the stopper is replaced, covered with tinfoil, paper or cloth and tied in place. Examinations should be made within 6 hours for impure waters and 12 hours for fairly pure waters. If examinations cannot be made within this period, the sample must be kept cold—between 40° F and 50° F. Even then changes may take place in the sample, such as multiplication of the bacteria.

The total number of bacteria is determined by mixing the sample water with liquefied culture media and placing in a petri dish. This is then placed in an incubator for 24 hours, if the temperature is held at 37° C, or for 48 hours if the temperature is 20° C. Each bacterium in the water multiplies under those conditions into a colony which is visible without a microscope. Thus by counting the colonies on the culture media in the petri dish, the number of bacteria is known.

The examination for coliform bacteria is made by adding small portions of the water to tubes containing lactose broth. The formation of gas in these tubes in 24 or 48 hours indicates the presence of some of the coli-aerogenes group of bacteria, and casts decided doubt on the quality of the water. Further tests are available for confirming the presence of these bacteria, and even for differentiating between fecal and non-fecal types.

The above is but a brief outline of the procedure,

which involves careful sterilization of all apparatus, exact dilutions, etc. These cannot be learned from any text. Attendance at Short Schools or other courses, or work in a laboratory is necessary before reliable results can be obtained.

The microscope is used in the examination of water for the confirmation of suspected bacteria, but even more in the identification of algae and other aquatic organisms. This latter subject will be discussed in greater detail in connection with algae and taste and odor control, in a later section of this text.

VI. An Outline of Water Treatment Methods

1. *Surface Water.*—Water purification is accomplished by one or more methods of treatment. The storage of water in reservoirs accomplishes considerable purification through sedimentation, and the action of sunlight and other natural agencies. Water is drawn from reservoirs through screens which prevent the ingress of twigs, leaves, fish and other objects; the water from the reservoir, if clear and otherwise satisfactory in accordance with the standards outlined in the preceding section, may be suitable for use with no other treatment than chlorination. In many cases, however, turbidity, color and bacterial content are so great as to necessitate filtration of the water before use.

Effective filtration requires that the water, before application to filters, be clarified by coagulation and further sedimentation. To accomplish this, such chemicals as aluminum sulphate or iron sulphate are added. In some cases, lime or soda ash must be added to insure an effective coagulation. The water is usually chlorinated after filtration, but there is an increasing tendency to apply chlorine at the start of the water treatment process.

Where iron or manganese, hardness, or other mineral constituents are present in the water, special treatment must be provided to neutralize or remove these. These processes will be described in more detail in the following sections.

2. Ground Waters.—Water from wells is seldom turbid or colored, but often contains much dissolved minerals. Filtration is, therefore, not usually necessary, but treatment to remove iron, manganese, carbon dioxide or hardness may be required. These methods of treatments will be discussed in succeeding sections.

3. Intakes and Screens.—Intake structures are needed to draw water from lakes or streams; merely laying the pipe out into the water is not satisfactory, for the pipe may sink into the mud, or may draw sand or debris along with the water. It is desirable that the pipe be protected from movement, and the intake be located somewhere near mid-depth of the water. This location avoids floating material, as trees, logs and leaves at the surface; wave action which may stir up sand or mud in the water; and ice; also stagnant water near the bottom, mud, silt or similar material.

Intakes vary greatly, according to the size of the water supply, depth and bottom character of the lake, direction and intensity of winds and currents, and quality of the water.

A screen should be placed over the pipe at the intake, or in the inlet structure of large intakes. Generally the screen should be designed only to exclude large objects, since removal and cleaning is not easy. A screen having a mesh of about one inch may be used. This prevents the entrance of large sticks, logs and trash. The mouth of the pipe or entrance to the pipe should generally be flared and the area of the screen openings should aggregate about twice the area of the pipe. A low entrance velocity draws less floating material into the inlet.

Operation.—It is desirable to have the screens at the intake removable, or other provision made for occasional cleaning. A rake can be used to remove any material caught on the screen. Occasional scrubbing and inspection is desirable.

In northern areas, anchor or frazil ice may cause troubles. Frazil ice consists of small crystals which are carried below the surface by even slight currents and which deposit on intakes or screens. Anchor ice forms directly on objects in shallow water. Metal surfaces are especially subject to ice clogging of this sort.

Occasional reversing of the flow of water from the pipe into the lake sometimes helps in removing ice accumulations. Large openings in the intake and low velocity through the intake reduce ice trouble. A boom of floating timber to create an area of still water around the intake is often helpful, especially in smaller reservoirs. Such a boom may also be advantageous in keeping leaves, twigs and other floating material away from the intake.

Small oil or kerosene burning units to generate steam quickly are often effective in removing or in relieving frazil or anchor ice clogging. A very small rise in temperature on the exposed surfaces is enough to free them from the ice.

There are several types of screens that can be installed at or near intakes that clean themselves automatically. These consist of an endless or jointed belt of screens which are moved slowly upwards by a small motor. The solids caught on the screen are removed at the top by a small jet of water and dropped into a trough.

This type of screen can be installed at an intake, if electric power is available, or at the treatment plant or reservoir. A $\frac{1}{4}$ or $\frac{3}{8}$ -inch mesh screen is commonly used, this being possible because the regular automatic cleaning does not permit clogging. Occasionally a finer screen is used. Denver employs a 60-mesh primarily to remove algae, slimes, etc.

Screens should be in duplicate if of the fixed type, or the moving type described just previously can be used. Double screens are often used.

Fixed screens should be scrubbed or squeegeed as necessary to keep them clean; debris collected in them should be removed. If possible to do so, the flow of water through them should be reversed or the water shut off and the wash water wasted. Revolving screens may be hosed down or scrubbed from time to time; lubrication on mechanical screens should follow the directions of the manufacturer.

3. Sedimentation.—Sedimentation consists in holding the water in, or passing it very slowly through, reservoirs, tanks, or basins. The particles of sand or clay that cause turbidity are about 2.65 times as heavy as an equal volume of water. If the water is held quiescent or practically so, much of this turbidity will settle to the bottom, but currents or eddies tend to hold it in suspension and prevent it from settling.

Sedimentation basins may be any size—from those that hold the water for only, 1, 2, 3 or 4 hours, up to large reservoirs, where the water is stored for weeks or even months. In some few cases, sedimentation alone will produce a clear and satisfactory water, except that all water should be chlorinated.

In other sections of the country where clay soils predominate, sedimentation alone will not remove the turbidity. Chemicals are then added—usually aluminum sulphate (commonly but erroneously called alum) or ferrous or ferric sulphate and lime. These chemicals produce an insoluble flocculent precipitate, called "floc," which settles quite rapidly, carrying with it even very fine particles of clay, and producing a clear water. After such treatment, the water must be filtered to remove the small particles of floc which do not wholly settle out.

Sedimentation without chemicals is called "plain sedimentation"; when chemicals are used to produce a floc and this is afterwards allowed to settle, the process is called "coagulation and settling." These are the two types of sedimentation; they will be considered separately later.

Operation of Plain Sedimentation Basins.—There is relatively little that the operator can do to improve the operation of plain sedimentation basins, other than to see that the inlets and outlets are kept clean, and that sediment is removed at proper intervals. Modification of inlets and outlets, and installation of baffles should be done only after careful study. The purpose of the inlet is to permit the entrance of the water into the basin with the least possible disturbance or agitation; and of the outlet to allow the water to flow out of the basin without creating undesirable currents of eddies. Baffles or partitions may be of value in creating an even flow through the tank, and to prevent any tendency toward "short circuiting" or direct flow from inlet to outlet. If these structures do not operate properly, careful consideration should be given to any contemplated changes before they are made.

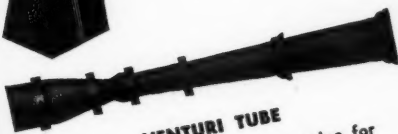
Cleaning Settling Basins.—Most plain sedimentation basins do not have any provision for quick and easy removal of the sediment that accumulates in them. At intervals—usually when the depth of sediment has reached 3 or 4 feet—the basins must be

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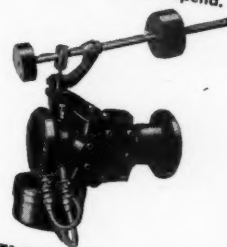
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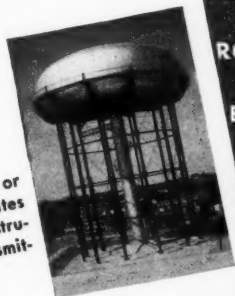
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CHRONOFLO INSTRUMENTS

Show flow, or level, at distant points. Simple, two wire transmission circuit.



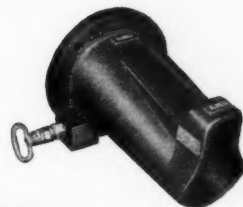
CHRONOFLO TRANSMITTER

Installed at standpipe or elevated tank, actuates distant Chronoflo Instrument. Similar transmitters for flow.



FLO-WATCH

Used with Venturi Tube or Nozzle, orifice, or Kennison Nozzle. Inexpensive, accurate mechanical meter.



KENNISON NOZZLE

For open flow, measures raw sewage, sludge, or effluent; trouble-free, accurate, simple, and easily installed.

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WATER AND SEWERAGE PLANT

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emptied of water and the sand and mud flushed out or removed with scrapers or other tools. It is important that settling basins be kept clean, as this improves settling and reduces taste and odor probabilities.

These data refer primarily to plain sedimentation. Fuller information regarding coagulation will appear in Section VII.

4. *Filtration.*—These are two types of filters—the slow sand filter, which operates at a rate of about 4 to 6 m.g.d. per acre; and the rapid sand or mechanical filter, which operates at the rate of about 125 m.g.d. per acre or 2 gallons per sq. ft. per minute. These are superficially similar, so far as the construction of the sand bed is concerned, but operate very differently.

The slow sand filter is not suited to treat water that contains turbidity due to clay particles. It is usually employed in connection with plain sedimentation and relatively clear waters. The rapid sand filter is used in combination with coagulation and settling, which process is employed to remove the greater part of the turbidity and prepare the water for the filter.

This text will consider rapid filters almost exclusively. Details of their construction and operation will appear in Section VIII.

VII. How Chemicals Are Used in Coagulation and Settling

1. *General.*—Coagulation is a preliminary step to prepare the water for filtration. It is not a complete treatment process. Nevertheless, proper preparation of the water, or "conditioning," as it is often called, prior to filtration is one of the most important steps in water purification. Study, research and care in this stage of treatment will pay large returns in reduction of filter troubles and in the quality of the water delivered to the consumers.

Basins or tanks for coagulation settling are usually designed to provide a detention period of 3 to 8 hours—the longer period in those sections where clay soils are predominant, and the water is nearly always turbid. In some places, plain sedimentation is used as a preliminary treatment, as much of the suspended matter can be removed, thus reducing the amount of chemical required.

The coagulation, aluminum sulphate or other suitable chemicals are added to the water. These react with materials present in the water (or with each other) and after a short period a flocculent and gelatinous precipitate forms. This attracts or envelops the finely divided particles of clay, silt and organic matter, and absorbs coloring material, forming particles of floc varying in size from those barely visible to feathery flakes. These floc particles settle quite rapidly and completely, leaving a clear water.

2. *Factors Affecting Chemicals.*—(a) The dosages of chemical required vary with the amount and kind of turbidity present, with the alkalinity or acidity of the water, with its pH value, with the temperature, and with other factors. Thorough mixing of the chemical with the water, and an adequate period of reaction and of settling are necessary for economy and good results.

(b) *Effects of Temperature.*—While the results vary with different chemicals, it is generally the case that slightly more coagulant is required at temperatures below 35° F to 40° F and above 65° F to 70° F. Chemical reactions are always slower and less complete at low temperatures, while at the higher temperatures there is sometimes a reabsorption of the floc.

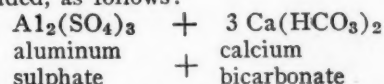
(c) *Effect of Alkalinity, Acidity and pH.*—The effect of these factors depends upon the type of coagulant used. Each one has its reaction range within

which it performs most successfully. These factors will be discussed in connection with each chemical.

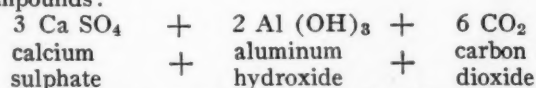
(a) Chemicals Ordinarily Used in Coagulation and Conditioning

1. *Aluminum Sulphate.*—Aluminum sulphate, usually called filter alum, and the chemical most commonly used in coagulation, has the theoretical formula $Al_2(SO_4)_3 \cdot 18 H_2O$. In order to form a floc, alkaline carbonates (calcium, sodium or magnesium carbonates) must be present in the water, and if these are not present, lime or soda ash must be added to supply the necessary alkalinity.

When calcium bicarbonate (called an alkaline carbonate) is present in the water, and aluminum sulphate is added, as follows:

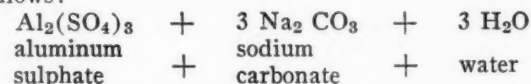


the chemicals present combine to form the following compounds:

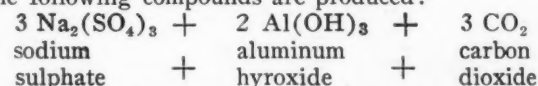


The aluminum hydroxide is the desired floc. It should be noted that a moderate excess of calcium bicarbonate does not interfere; it is not necessary to add enough aluminum sulphate to combine with it all. Only enough of the $Al_2(SO_4)_3$ is necessary to produce a floc satisfactory in volume and size of particles.

When sodium carbonate is present, instead of calcium bicarbonate, and aluminum sulphate is added, as follows:



The following compounds are produced:



The complete reaction, when aluminum sulphate is used, requires theoretically 7.7 ppm. of alkalinity for each grain per gallon (17.1 ppm.) of alum; but in actual practice each grain per gallon of alum requires 6 to 10 ppm. of alkalinity with which to react, and there should be also an excess alkalinity of 20 to 25 ppm. in the filtered water in order to prevent corrosion.

For instance, assuming that 8 ppm. of alkalinity is required for each grain per gallon of aluminum sulphate used, with a dosage of $Al_2(SO_4)_3$ of $1\frac{1}{2}$ g.p.g., there will be required $8 \times 1\frac{1}{2} = 12$ ppm. of alkalinity for the reaction with this amount of aluminum sulphate. There will also be required an alkalinity of 25 ppm. to prevent corrosion. Therefore a total of 37 ppm. of alkalinity will be required. If this is not present, it must be added in the form of lime or soda ash.

If there is not enough alkalinity to react, as above, some of the aluminum sulphate will remain in solution. If there is no reserve of alkalinity after the reaction, the water will be corrosive, due to the CO_2 released by the reaction, with the aluminum sulphate. Lime (CaO), hydrated lime ($Ca(OH)_2$), or soda ash (sodium carbonate, Na_2CO_3) can be used to furnish alkalinity; 0.5 grain of sodium carbonate combines with 1 grain of aluminum sulphate, and in doing so produces 3.4 ppm. of free CO_2 ; 0.5 grain of sodium carbonate will combine with 3.6 ppm. of CO_2 . Therefore 1 g.p.g. of sodium carbonate reacts with 1 g.p.g. of aluminum sulphate, furnishing the required alkalinity and combining with the free CO_2 produced. When lime is used, 1 g.p.g. of aluminum sulphate will combine with 0.35 g.p.g. of lime, and the CO_2 produced by the reaction

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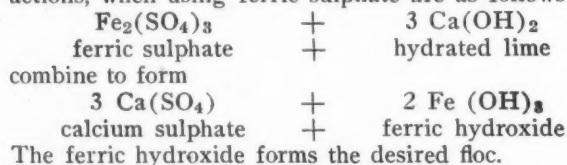
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is neutralized by about 0.35 g.p.g. of lime.

Aluminum sulphate reacts best at pH values of 5.5 to 8.5. A minimum dosage in clear water is about 0.3 g.p.g. Larger amounts are required for turbid waters, but there is no fixed rule to govern dosages. Experiments and experience with each water form the best guide. Large flakes of floc indicate a dose larger than is needed. In cold or very warm weather larger dosages may be needed.

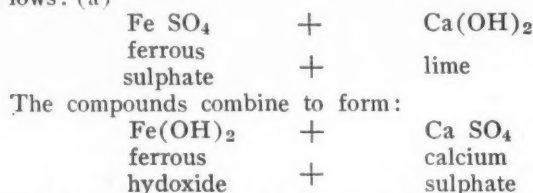
2. *Ferric Sulphate.* Ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$) is widely used in coagulation, principally in the granular form known as Ferrisul. This is a free-flowing chemical that can be fed dry. In general, ferric sulphate behaves just as does aluminum sulphate, but will produce a satisfactory floc over a somewhat wider pH range. It has particular advantages where manganese is present in sufficient quantity to require removal. The reactions, when using ferric sulphate are as follows:



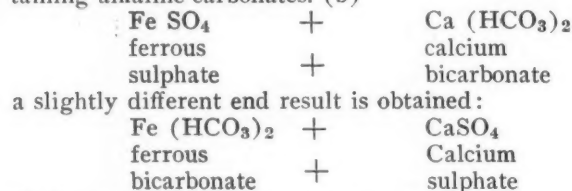
The ferric hydroxide forms the desired floc.

3. *Ferrous Sulphate.*—This chemical frequently called copperas, should not be confused with copper sulphate which is used for algae control. It has the formula $\text{FeSO}_4 \cdot 7 \text{H}_2\text{O}$. It is available in lump form, or as the granular sugar sulphate of iron, in which form it contains less than 7 molecules of water.

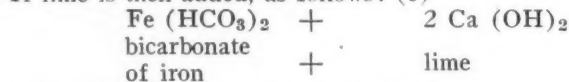
Lime must be added to the water to produce a satisfactory reaction. When it is added to the water before the ferrous sulphate is added, the reactions are as follows: (a)



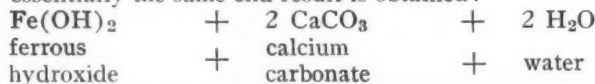
When the ferrous sulphate is added to water containing alkaline carbonates. (b)



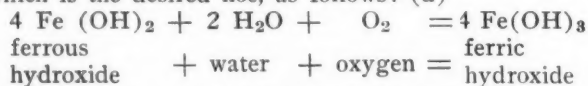
If lime is then added, as follows: (c)



essentially the same end result is obtained:



In either case the dissolved oxygen in the water oxidizes the ferrous hydroxide to ferric hydroxide, which is the desired floc, as follows: (d)

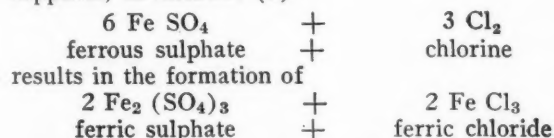


When ferrous sulphate is used, dosages will be approximately the same as when alum is used. The lime dosage, with relatively clear waters, will be about 0.4 grain of lime per grain of ferrous sulphate, and the amount of lime required increases with the turbidity of the water, so that when the turbidity is considerable, as much lime will be required as ferrous sulphate.

For any water, enough lime is required to form the reaction with the ferrous sulphate used; to remove the CO_2 present in the water; and to provide an excess of not more than 4 or 5 ppm. About $\frac{1}{2}$ ppm. of dissolved oxygen must be present in the water or provided otherwise for each grain per gallon of ferrous sulphate used. Where the amount of oxygen is deficient, prechlorination, which has an oxidizing effect, may be employed.

Ferrous sulphate and lime may be used advantageously where the water is hard and contains considerable turbidity. These chemicals are not suitable for the treatment of colored water, as soluble compounds may be formed in combination with organic matter, causing a dark color in the treated water, or fixing the color that exists.

4. *Chlorinated Copperas.*—Chlorinated copperas is made at the point of use by adding chlorine to a ferrous sulphate solution. The addition of the chlorine to the copperas, as follows: (a)



Theoretically one pound of chlorine is required to react with 8 pounds of ferrous sulphate; in practice about 10% extra should be added to insure complete oxidation of all the copperas. When chlorine is added to act as a disinfectant, enough extra may be added to react with the copperas. The coagulating agent is the ferric hydroxide, as in 3 (d) above, which is obtained through reaction of the ferric sulphate with the alkaline carbonates in the water.

Chlorinated copperas is effective in removing color, as the hydroxide forming the floc is insoluble, even over a wide pH range. Coagulation and floc formation are usually best at a pH below 7, especially where color removal is a principal object of treatment.

5. *Lime.*—Lime is available as calcium oxide, CaO or hydrated, $\text{Ca}(\text{OH})_2$. The calcium oxide is the quicklime and must be slaked before use, and fed as a suspension. Hydrated lime can be fed dry. When used in large quantities, as in a large plant, the quicklime is cheaper, but hydrated lime is handier for the small plant. It does not deteriorate when stored in a dry place and is obtainable in handy-sized paper bags.

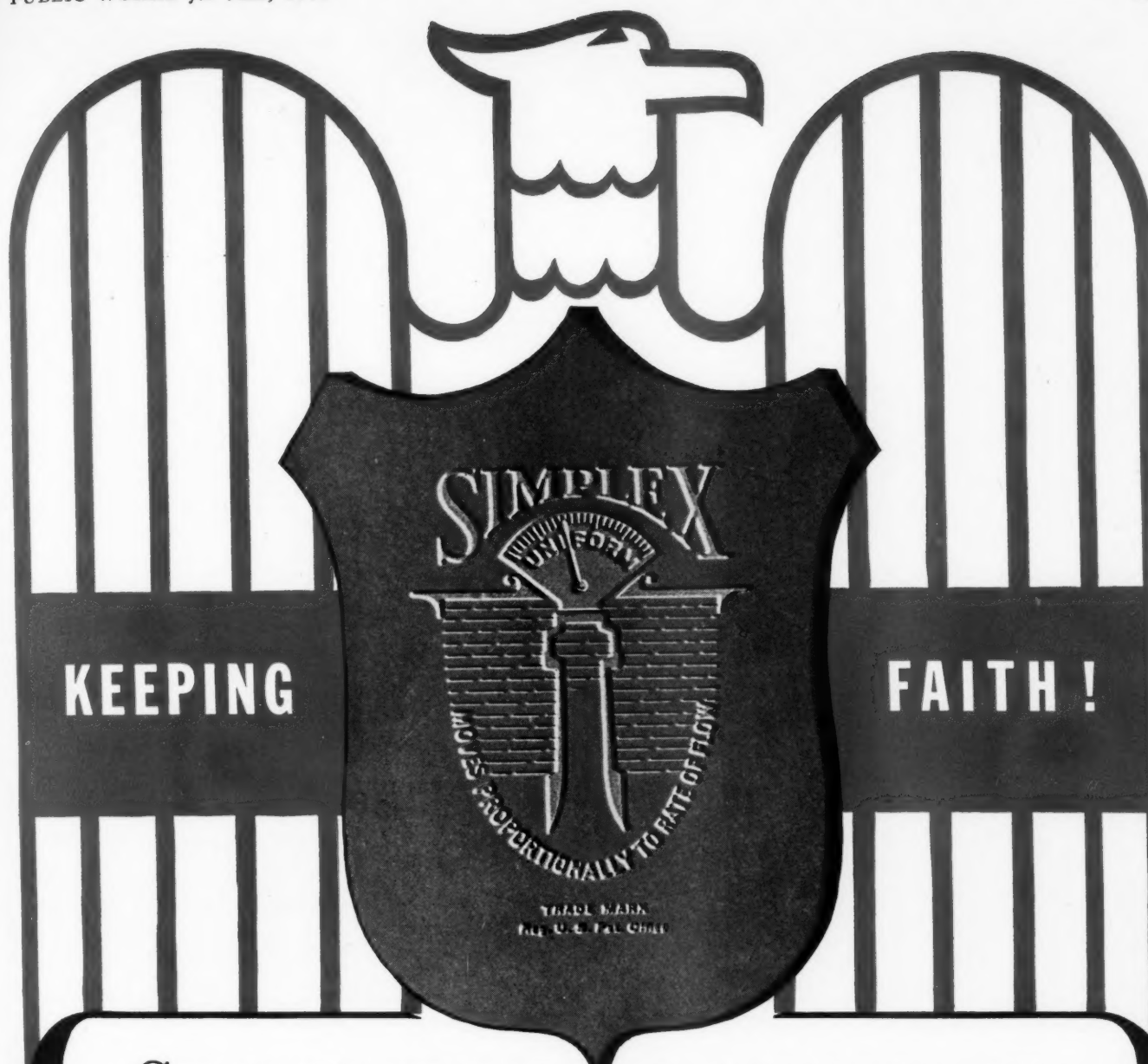
When using lime, the calcium content is important, and must be known in order to dose properly. Quicklime may vary from 75% to 99% CaO , and should be bought and used on the basis of its CaO content. Hydrated lime varies between 85% and 99% $\text{Ca}(\text{OH})_2$.

Assuming 100% CaO in the quicklime and 100% $\text{Ca}(\text{OH})_2$ in the hydrated lime, 75.7 pounds of quicklime equals 100 pounds of hydrated lime; and 100 pounds of quicklime is equal to 132 pounds of hydrated lime.

These relationships must be modified by the contained percentage of CaO or $\text{Ca}(\text{OH})_2$ in the lime used. For instance, if the hydrated lime contains 95% $\text{Ca}(\text{OH})_2$, it will require $132 \div 95 = 140$ pounds to equal 100 pounds of 100% CaO .

Lime is used in coagulation to provide added or "artificial" alkalinity for reactions with aluminum sulphate and copperas, and also for softening, which will be discussed later. It may be used alone as a coagulant for waters containing a large amount of magnesium, by the precipitation of magnesium hydroxide by excess lime.

6. *Soda Ash.*—Soda ash is the common name for



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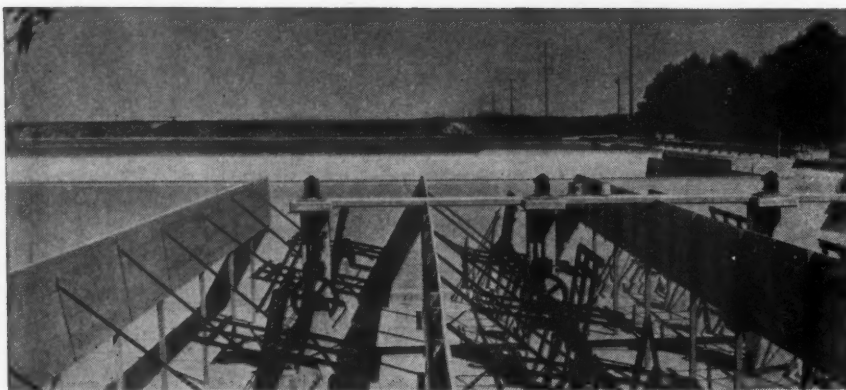
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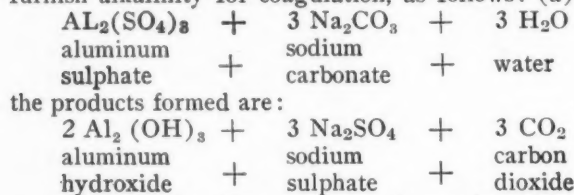
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Dorcco flocculator installed in rectangular basin ahead of sedimentation tanks at Corpus Christi, Texas.

sodium carbonate, which has the formula Na_2CO_3 . It is used, as already stated, to furnish artificial alkalinity for coagulation, and also for softening water. Most soda ash is 98% or more sodium carbonate.

When added to water with aluminum sulphate to furnish alkalinity for coagulation, as follows: (a)



An excess of sodium carbonate is usually added to combine with the CO_2 . This produces sodium bicarbonate which does not increase hardness.

Though soda ash is more costly than lime, it has advantages for coagulation in the small plant. It is easy to feed, eliminates "after precipitation" and does not increase hardness.

7. *Sulphuric Acid.*—Sulphuric acid, H_2SO_4 , is sometimes used in water purification principally to reduce the pH of certain colored waters. Most colored waters coagulate best when slightly acid, and the lower pH may also reduce the amount of aluminum sulphate required for coagulation.

8. *Applying Chemicals.*—Thorough mixing of the chemicals with the water is necessary for the reaction to be complete. The water to be coagulated is often given preliminary sedimentation to remove as much as possible of the suspended matter. In some modern plants, the water, after addition of the coagulating chemical, is mixed vigorously for a few minutes, followed by a slower mixing (called "flocculation") for a longer period, and allowed to settle. In other types of plants, mixing and floc formation are combined in one operation.

Aluminum sulphate may be fed dry or as a solution. In either the large or the small plant, the use of ground aluminum sulphate is often preferable as it eliminates the trouble of making up solutions. Ferric chloride is fed as a solution; ferric and ferrous sulphate are ordinarily fed dry.

9. *Silicate of Soda* has been found to have, under certain conditions, the property of enlarging alum floc particles, resulting in more rapid and complete sedimentation and a clearer effluent.

(b) How to Compute Dosages of Chemicals

1. *General.*—There is no rule or formula for determining coagulant doses for best clarification. Acidity, alkalinity, the character and amount of turbidity, temperature, color and other factors influence the amount and even the type of chemical. Results obtained

in another plant, even one treating water of a similar nature, can be used only as a rough guide. Laboratory tests are valuable indicators of the probable dosages that will be required. In the final analysis, experience gained by close observation and study and actual records of results at the plant in question are the best guide.

2. *Procedure in Laboratory Tests.*—In making these tests, a measured amount of the water to be coagulated is placed in beakers or jars, and dosed with different amounts of co-

agulant. The water and coagulant is then stirred until the floc forms, and this is allowed to settle, duplicating as closely as possible plant operations.

There are available several excellent devices for this work. These consist of 1, 2, 4 or 6 beakers, each holding about 1 liter, with electrically driven paddles for stirring the water to form the floc. Some of them have arrangements for varying the speeds of the paddles. Equipment with 4 or 6 jars is preferable. If such equipment is not available, one quart fruit jars may be used, and the stirring done by hand, with a glass rod or an eggbeater. It is best to mark each jar or beaker to indicate exactly one liter; or 1 quart, if this unit of measure is to be used.

a. Preparing the Solutions

1. *General.*—It is best to use the chemicals at hand in the plant. No allowance for strength or purity need be made in this case.

2. *Coagulants.*—While the use of grains per gallon is most common in coagulation, the use of parts per million is preferable for making laboratory tests, especially since the two terms are easily converted. Add 10.0 grams of aluminum sulphate, ferric sulphate, or other coagulant to 1 liter of distilled water. One ml. of this solution, when added to 1 liter of the water to be treated is equal to a dose of 10 ppm. or about 0.6 g.p.g.

3. *Soda Ash.*—Add 10.0 grams of soda ash to 1 liter of distilled water. One ml. of this solution when added to 1 liter of water is equal to a dose of 10 ppm.

4. *Lime.*—Using 1 liter of distilled water, add 10 grams of lime. One ml. of this solution, when added to 1 liter of water gives a dose of 10 ppm.

5. *Dosages in Grains per Gallon.*—To prepare a solution for dosages in grains per gallon, add 17.1 grams of the chemical to 1 liter of distilled water. One ml. of this solution when added to 1 liter of the water to be treated equals a dosage of 1 grain per gallon.

6. *Dosages on Quart Basis.*—To prepare a solution for dosages for quart jars, add 8.95 grams of the chemical to 1 quart of water. One ml. of this solution, added to 1 quart of water gives a dose of 10 ppm.

b. Dosages of Alkaline Waters

1. *Procedure.*—To each of 6 jars (a lesser number may be used) containing 1 liter of the water to be treated, add different dosages of aluminum sulphate. Alkaline waters do not normally require the addition of lime or soda ash to furnish the alkalinity for the reaction with aluminum sulphate, if the alkalinity present in them is sufficient.

Assuming the test is being made with 6 jars and that the solution being used contains 10 grams of aluminum sulphate to 1 liter of water, the jars may

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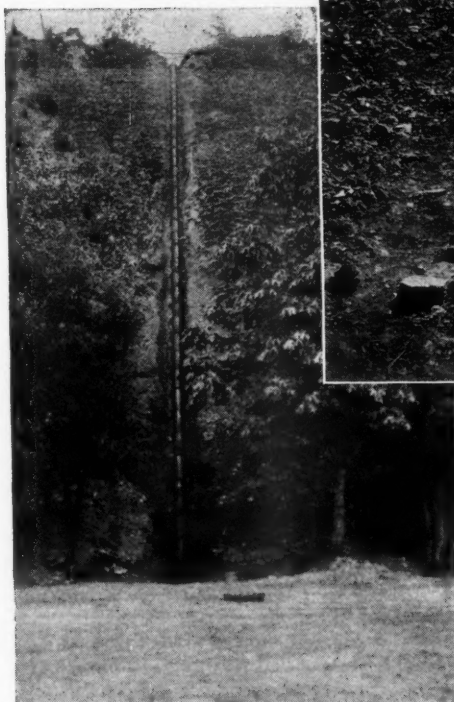
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be dosed as follows:

Equivalent Aluminum Sulphate Dose

Jar No.	Dose in ml.	in ppm.	in g.p.g.
1	1	10	0.58
2	2	20	1.17
3	3	30	1.85
4	4	40	2.34
5	5	50	2.92
6	6	60	3.50

After stirring for about 15 minutes, allow the samples to stand and note the floc that forms. If none forms, the water is probably deficient in alkalinity or is so excessively turbid as to require even more aluminum sulphate. The smallest dosage of chemical that produces a good floc that settles well should be used. A large flaky floc indicates that the dose of chemical is unnecessarily large, and may be reduced somewhat. Note the pH of the water in the jar showing the most satisfactory floc.

c. Water Deficient in Alkalinity

1. The factors involved in coagulation with aluminum sulphate have been mentioned. For each dosage of 1 grain per gallon of this chemical, 7.7 ppm. of alkalinity are needed, and there should be also an excess of 20 to 25 ppm. to prevent corrosion.

If the alkalinity of the water is known, the requirements for coagulation can be computed approximately, and the deficiency in excess of alkalinity thus determined. The test for alkalinity is a simple one and should be performed if possible in advance.

Assuming that the natural alkalinity of the water to be treated is 22; that each grain per gallon of aluminum sulphate requires 8 ppm. of alkalinity (instead of the theoretical 7.7 ppm.); and that an excess alkalinity of 25 ppm. is desired, the amount of lime or soda ash that must be added for any dosage of aluminum sulphate is computed as follows:

Dose of Aluminum Sulphate	Alkalinity for Reaction	Need for Reserve	Total Alka.	Natural Alka.	To be Added
1 g.p.g.	8	25	33	22	11 ppm.
1½ g.p.g.	12	25	37	22	15 ppm.
2 g.p.g.	16	25	41	22	19 ppm.
2½ g.p.g.	20	25	45	22	23 ppm.
3 g.p.g.	24	25	49	22	27 ppm.
3½ g.p.g.	28	25	53	22	31 ppm.

The same procedure is now followed as for the use of aluminum sulphate in alkaline waters, except that soda ash or lime solution, prepared as already described, is first added to each jar to give the dosage shown in the last column of the above table, that is, 1.1 ml. for jar No. 1; 1.5 ml. for jar No. 2, etc.

Results given by such tests are valuable as a guide in finding what dosage is best on a plant scale. The dosage shown as best by the jar test may not be the best one, in actual plant practice, but it will usually be close to it, and with some modifications will usually give excellent results.

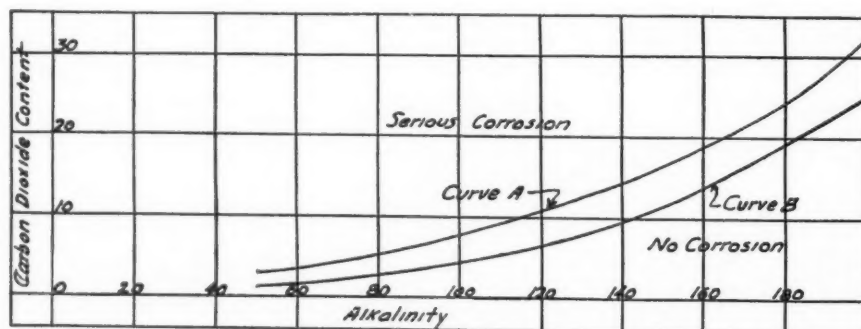


Fig. A. Relation between corrosion, alkalinity and CO₂.

This test does not apply well in certain waters along the Southeastern Seaboard.

2. *Example.*—From the jar test, it is found that 1½ g.p.g. of aluminum sulphate and 15 ppm. of alkalinity give best results. The flow of water to be treated amounts to 720,000 g.p.d. How much chemical is needed?

3. *Solution.*—A dosage of 1½ g.p.g. equals 142 x 1½ = 213 pounds per million gallons. The flow is .72 m.g.d. Thus the aluminum sulphate required is .72 x 213 = 153.4 pounds per day. There must be added 15 ppm. of soda ash or its equivalent. The amount required is 15 x 8 1/3 x .72 = 90 pounds per day of soda ash.

d. Corrosion and Its Prevention

1. The corrosiveness of a water depends upon its pH value, CO₂ content and alkalinity. The best method of preventing corrosion is to adjust these elements so as to deposit a thin coating of calcium carbonate on the interior of the piping system. This must be kept thin or it will clog pipes, water heaters, etc.

The CO₂ content is the important factor; an excess increases corrosiveness, but some is necessary to hold the alkaline salts, as calcium and magnesium bicarbonates, in solution and prevent deposits in excess of the amount desired.

The control of the CO₂ content is best accomplished by adding an alkali, as lime or soda ash thus increasing the alkalinity; lime is generally used because of its economy.

The first step in control of corrosion is to determine the CO₂ content and the alkalinity to methyl orange. These values can be plotted on the chart Fig. A, which is based on a similar chart in Water Supply Control, by C. R. Cox and published by the New York State Department of Health, and which shows the relationship between alkalinity, CO₂ content and corrosiveness. For instance a water having an alkalinity of 100 ppm. and a CO₂ content of 5 ppm. would be only slightly corrosive; but if the alkalinity were only 50 ppm., and the CO₂ content 5 ppm., it would be seriously corrosive. Therefore, increasing the alkalinity reduces the corrosiveness.

The relationship between pH and alkalinity is shown in Fig. B, which is from the same source as Fig. A. This illustrates the effects of pH and alkalinity. On this are shown three curves: If the pH and alkalinity, when plotted, fall along the line C, the water may be mildly corrosive, but iron stains will be prevented. If pH and alkalinity fall along curve B, both corrosion and deposits on the piping will be prevented. If the values are as shown by curve A, a protective coating of calcium carbonate will be built up on the pipes. If values shown on A are exceeded, excessive deposits may form; if values are below curve C, corrosion will take place.

2. *Determining Required Lime or Soda Ash.*—(a) The simplest method of determining the amount of lime or soda ash necessary to prevent corrosion is by the *marble test*. Place a sample of the water in a beaker or a wide-mouthed bottle, and in the water place several pieces of pure calcium carbonate (also called calcite). Powdered calcium carbonate may be used, as it is quicker and often easier. The test should be made in a closed container. The CO₂ pres-

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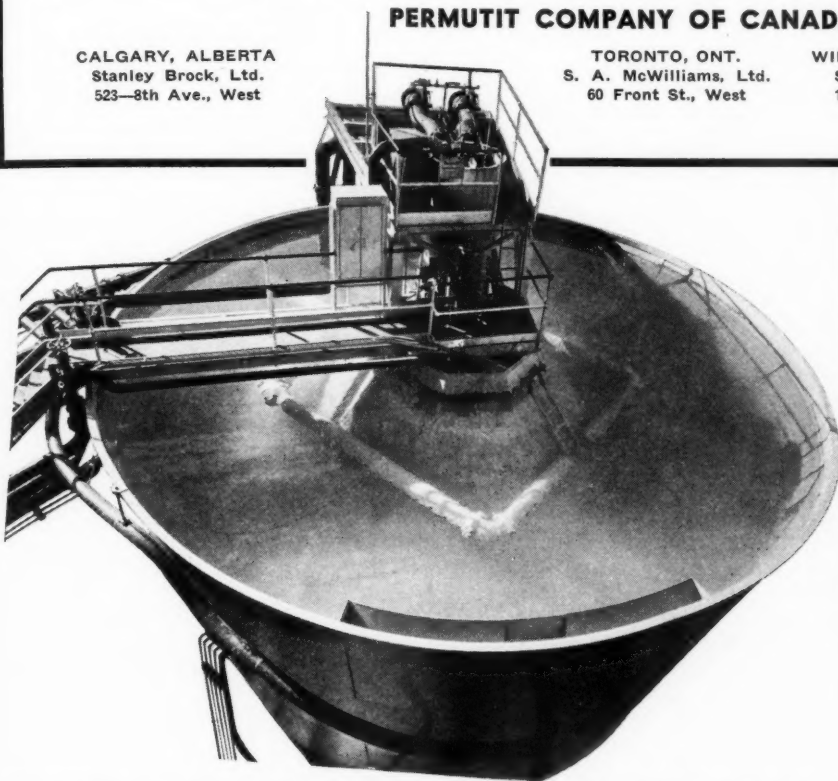
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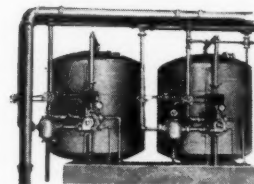
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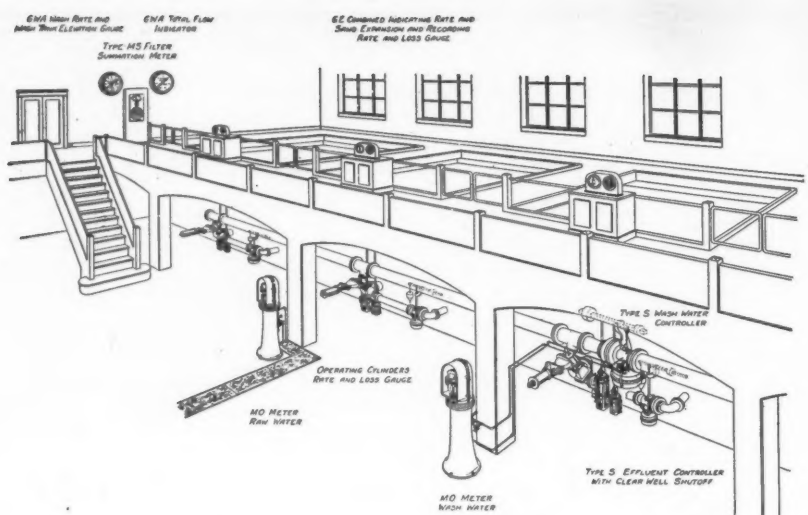
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A typical filtration plant, showing various gauges and meters.

ent in the water dissolves the calcium carbonate to bicarbonate. This reaction continues until all the corrosive elements have been neutralized, during which time the pH value increases. Make pH tests from time to time; when the pH no longer increases, but remains constant, the water is stable. It is then only necessary to add to the water to be treated sufficient lime or soda ash to raise the pH value to that finally shown on the marble test.

To compute the amount of lime necessary, a jar test similar to that already described is simplest. To make a lime solution, add 10 grams of lime to 1 liter of distilled water; one ml. of this solution added to one liter of the water to be tested equals a dosage of 10 ppm., or 83 pounds per million gallons. It is not necessary to know the CaO content of the lime, as the dosage is computed directly in pounds per million gallons. Add the lime solution, testing for pH after each addition. When enough lime has been added to raise the pH to that determined by the marble test, the necessary lime dosage in pounds per million gallons equals 83 times the number of ml. of lime solution used.

(b) When the alkalinity and CO₂ content are known, the needed amount of lime can be computed directly. One part per million of 100% CaO will react with 0.8 ppm. of CO₂; on the basis of 88% CaO content, 1 ppm. of lime will react with 0.7 ppm. of CO₂. Requirements of a water having CO₂ content of 10 ppm., a methyl orange alkalinity of 90 ppm., and no phenolphthalein alkalinity, would be computed as follows:

The free CO₂ is 10 ppm.; the halfbound CO₂ is 44% of the alkalinity, or 39.6 ppm., the total CO₂ to be neutralized is $10 + (90 \times .44) = 49.6$ ppm. There will be required (using 88% CaO lime), $49.6 \div 0.7 = 71$ ppm. or $71 \times 8.3 = 589$ pounds per million gallons.

VIII. Filters and Their Operation

(a) 1. *General*.—A filter is a bed of sand through which the water passes. During the passage of the water through the sand practically all of the suspended solids, some of the dissolved solids and most of the bacteria are

removed. This action is due in part to the straining action of the sand, and in part to a jelly-like formation which coats the grains of sand and entraps the fine particles of material and also the bacteria, as these are carried through by the water.

In order that the sand bed may work most effectively, it must be so constructed that water can be applied to the surface of the bed and collected at the bottom. In practice this means that the filter is placed in a concrete or steel tank; that underdrains and a collecting system are built beneath it to collect the filtered water; and that valves and controls are needed to regulate the passage of the water to and through the filter. The water must flow to and through the filter at a uniform and proper rate.

The general structure of a filter is shown in the accompanying illustration.

2. *Sand for Filters*.—For filter purposes, quartz sand or silicates (sometimes also anthracite coal), which are not affected by characteristics of the water, should be used. Ordinary bank sand cannot be used without screening, washing and grading to produce the correct size, and unless it is free from lime and magnesium carbonates.

If the sand is too fine, it will offer excessive resistance to the passage of the water and will require frequent cleaning; if too coarse, it may remove too little of the material that it is desired to take out. From experience over a long period of years, the sizes of sand that give best results have been determined. Two important factors, aside from those of the composition of the sand are "effective size" and "uniformity coefficient."

3. *Effective Size of Sand*.—The effective size of a sand is that size such that 10% of the sand grains by weight are smaller than it. This factor is simply a means of describing the fineness of a sand in terms that can be used with precision and exactness in water works practice. When described by this term, a fine sand would be one having an effective size of 0.17 or 0.18 millimeters; and a coarse sand would be one having an effective size of 0.45 or 0.50 m.m.

4. *Uniformity of Sand*.—The uniformity of a sand is another characteristic of importance in water purification. The uniformity coefficient is the ratio between the effective size and that size such that 60% of the sand is finer than it. Both uniformity and effective size are necessary to describe a sand.

(b) Mechanical or Rapid Sand Filters

1. *General*.—A rapid sand filter consists of a bed of sand about 24 or 30 inches deep which is supported

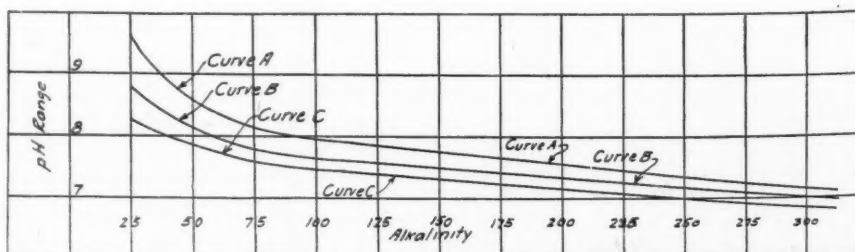


Fig. B. Relations between pH, alkalinity and corrosion.

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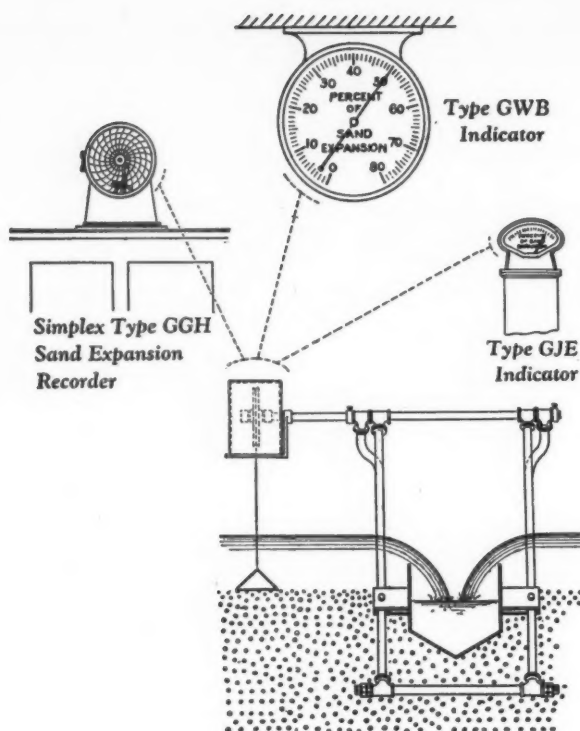
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Simplex sand expansion indicator and recorder.

on a layer of graded gravel 12 to 18 inches deep. The sand usually used in a filter of this type should have an effective size of 0.35 to 0.50 m.m., and a uniformity coefficient of 2.0 or less; that is, the sand should be quite uniform in size. The gravel ranges from 2-inch or 3-inch pieces at the bottom to coarse sand at the top.

The rapid sand filter operates at a rate of about 125,000,000 gallons per acre per day, or 2 gallons per square foot per minute. Because of this rapid rate, and the volume of water filtered special provisions for frequent and rapid washing are necessary.

This is accomplished by reversing the flow of water through the filter, and by passing it upward through the sand at a rapid rate. This washes dirt out of the sand; the dirty water flows off into wash water troughs or gutters and is wasted.

Before filtration, the water is always conditioned by coagulation and settling, as previously described. This also is important in insuring good filtration and a clear water. Particles of the floc which do not settle out collect on the surface of the sand and form a mat which aids in straining all the suspended matter and most of the bacteria from the water.

2. Size and Arrangement.—

Rapid sand filters are most often constructed as rectangular units, side by side, in two rows, between which is a passageway containing operating and control units. The necessary piping, controllers, etc. are frequently placed under this passageway in a pipe gallery.

A filter unit 18 ft. by 20 ft. will handle about 1 m.g.d. Units vary from ½ m.g.d., or even less, to 2 m.g.d. in the larger plants. In very small plants, the units are frequently circular.

3. Loss of Head.—The gravel bed depth (12 inches or more),

plus the depth of sand bed (usually 30 inches), plus the height of the wash water troughs above the sand (usually 24 inches), plus the freeboard above the troughs (usually some 4 feet) make up the depth of the filter. On the above basis, the depth would be 9 feet 6 inches, which would be the head available without employing negative head or suction.

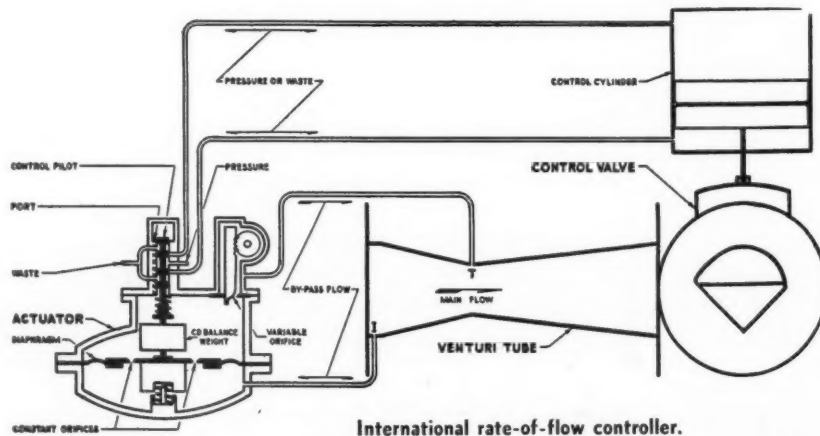
When the filter is first put in operation after washing, the loss of head due to friction in passing through the sand is small—often about a foot. As the filter becomes dirty, this increases; when it becomes as much as 7 to 9 feet, the filter must be washed.

This variation in loss of head requires the use of rate controllers so that a uniform rate of filtration is maintained at all times. The maintenance of a uniform rate of filtration is very important. A sudden increase in the rate of flow may cause breaks in the bed; and a rapid decrease may release air held in the water, causing air-binding.

4. Rate Controllers.—A rate controller is designed to regulate automatically the flow through the filter so as to maintain a uniform rate of discharge regardless of the change of loss of head in the sand, or of the change of elevations of the water in the filter and in the clear water basin. It does this by consuming or wasting pressure or head. It continually adjusts its valve openings as necessary so that the pre-determined or "set" rate shall pass through them from the start of the filter run until the valves are wide open. It is a mechanical hand which controls the valve during the entire run of the filter, and for best results should be set to maintain a rate of not more than 2 gals. per sq. ft. per minute.

The rate controller is a vital part of the filter plant, since it maintains these conditions essential for effective filtration. It may do this by regulating the flow through the sand bed while it is operating with an excess head; or it may operate as a safety device to limit the maximum rate through the filter when it is desired to keep the clear well level as near as possible to the filter level. All rate controllers consist essentially of a venturi tube which produces a differential pressure which operates a diaphragm actuator or hydraulic piston to position the controller.

5. Checking Rate of Flow Through Filters.—Operators can calculate the rate of flow through the filter, thereby checking the rate controller, as follows: Fill the filter with water; shut off the influent line; determine the time necessary to filter down one foot. For example, if it requires 4 minutes for the water to drop one foot, the rate of filtration is $7.48 \div 4 = 1.87$ gals. per square foot per min. This multiplied by the filter area will give the rate in gallons per minute for the entire filter unit; and this result multiplied by



1440 will give gallons per day.

6. *Washing the Filter.*—When the loss of head in the filter has reached the point where washing is necessary, the influent valve is closed, and the water is drawn down below the tops of the wash water troughs, the filtered water outlet being closed. Water is then admitted slowly to the underdrain system, and then more rapidly until the usual washing rate is attained.

In most plants this rate is 15 gallons per square foot per minute, or $7\frac{1}{2}$ times as fast as the filter rate. Also since there are $7\frac{1}{2}$ gallons in a cubic foot, the rate is 2 cu. ft. of water per square foot and the "rise" or upward velocity of the water is 24 inches per minute. On some of the newer plants, higher rates are used (as high as 36 g.p.m. per square foot).

The upward flow of water "floats" the sand, expanding it by 40% to 50% of its volume, and washes out the dirt; the dirty water overflows into the wash water troughs and out through the waste drain. Washing should continue until there are larger clear areas in the wash water as it rises through the filter. Washing will ordinarily take 7 to 10 minutes. When it is completed, the wash water valve is closed; the waste or sewer valve is closed, and the influent valve is opened sufficiently to bring the water in the filter to its normal level. The water is then allowed to filter to waste for at least 3 to 5 minutes in order to build up a mat on the surface of the sand sufficient to produce a clear effluent. Bacterial removal is not very good immediately after washing.

7. *Air Wash.*—Some filters have small pipes between the sand and gravel layers, which pipes are for the purpose of carrying air under pressure to agitate the sand. This air is furnished from a compressed air tank or from a compressor unit. In washing, the influent valve is closed and water drawn down nearly to the surface of the sand. The air is then applied at the rate of 2 to 5 cu. ft. of air per square foot of filter per minute for 3 or 4 minutes. After the agitation and stirring have been accomplished, the air valve is closed, filtered water turned into the underdrains, and washing carried on as before described. Less wash water is used—as a rule from 6 to 10 gallons per square foot per minute.

8. *Surface Washers.*—There are several types of surface washers, among which are the Palmer revolving and the Baylis, which is stationary. Both wash the sand through agitation by jets of water. This type of washer may reduce wash water use, frequency of washing and operating difficulties.

9. *Determining the Rate of Wash.*—A simple method of determining the rate of wash is recommended by Charles P. Hoover, as follows: Draw down the water to the top of the wash water trough; shut the wash water outlet valve; determine time for wash water to rise two feet. For example, if the wash water rises 2 feet in exactly one minute, the rate of wash will be $2 \times 7.48 = 14.96$ gallons per square foot per minute.

10. *Measuring Sand Expansion.*—The upward velocity of wash water should be sufficient to expand the sand from 40% to 50%; that is, with a sand bed 24 inches deep, the depth during washing should be 33 to 36 inches. During the summer, there may be less sand expansion; even not enough to insure proper washing at the 15 g.p.m. rate. This is probably due to the higher temperature and lower viscosity of the wash water, and it may be necessary to increase the wash water rate.

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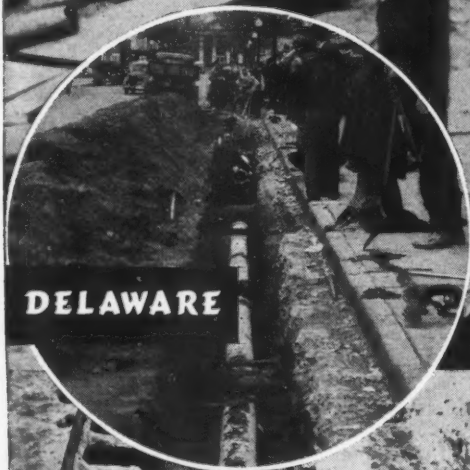
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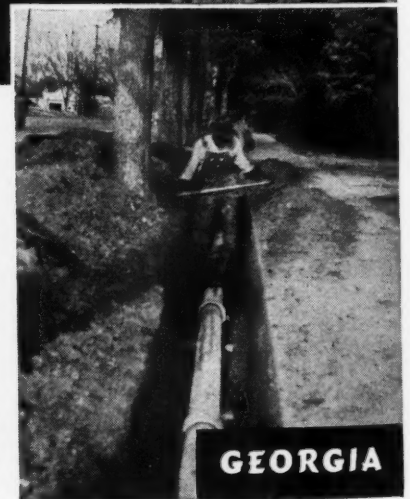
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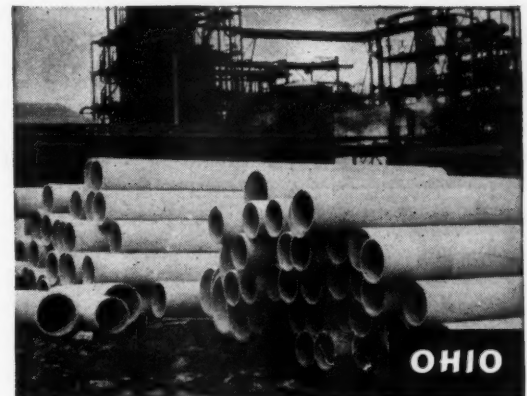
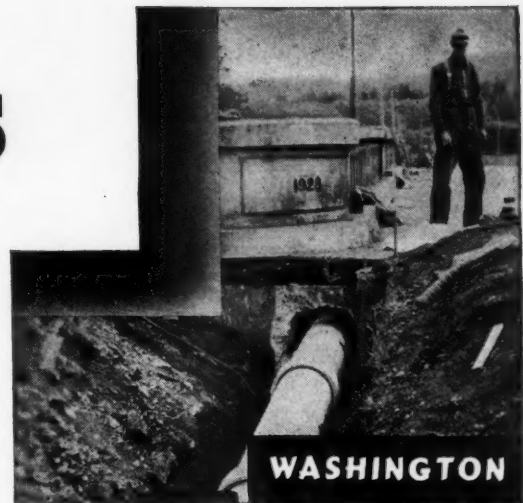
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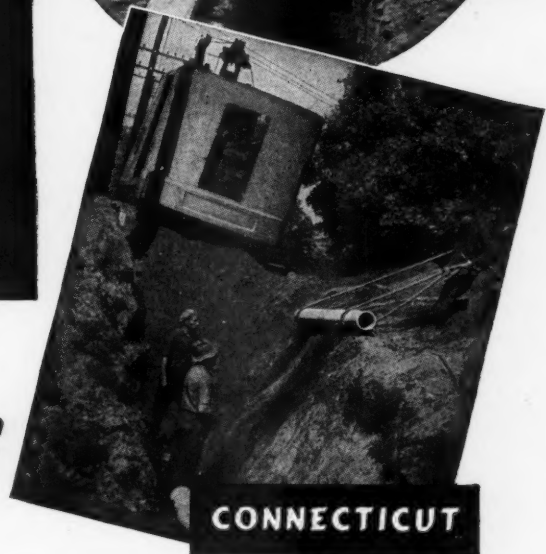
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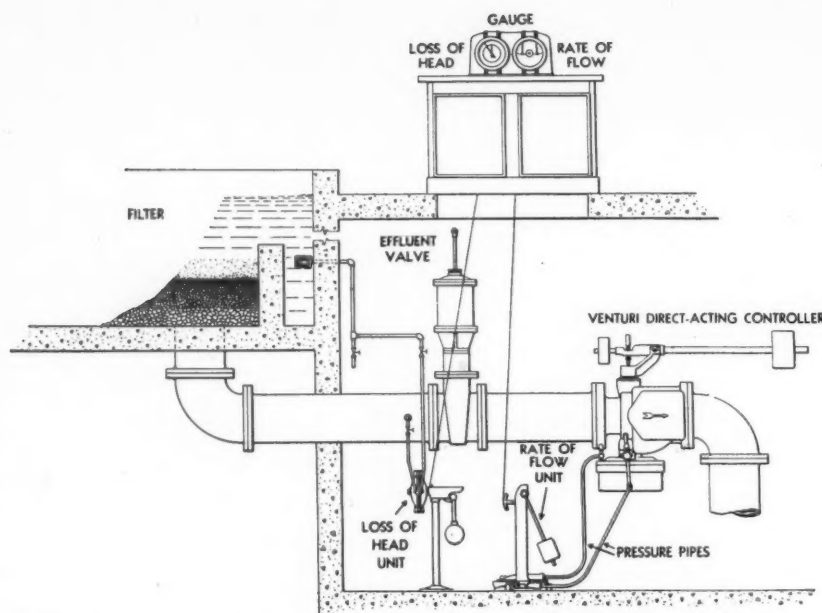
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may be purchased. A home made unit can be utilized by fastening of small metal cups (about 1 inch in diameter and $\frac{1}{4}$ inch deep) to a 24 inch rod at intervals of 2 inches, the upper cup being 6 inches from the top of the rod. The rod is fastened to the wash water trough so that the topmost cup is 6 inches below the lip of the trough. When the bed is washed, any deposit in the cups will mark the height to which sand has been carried by the wash water. For instance, if the cup 12 inches above the normal level of the sand bed contains sand, but the cup 14 inches above the bed does not, the expansion will be at least 12 inches, or 50% of the sand with a 24 inch bed.

Samples from the wash water trough, if placed in bottles and allowed to settle, will show if sand is being lost in washing. The loss of the finest sand from a new filter may be expected at first and is not objectionable.

(c) Correcting Rapid Sand Filter Operating Difficulties

1. *Preparation of Water for Filtration.*—Most or many of the troubles that occur are due to improper or inefficient preparation of the water before its application to the filters. Particular attention should be given, in mixing the chemical, in coagulation and in settling, to the removal of suspended matter, color, and other substances that may interfere with adequate filtration or may cause filter operating difficulties.

2. *Mud Balls.*—Mud balls may form in or on the sand. These generally indicate that the water applied to the filter has been imperfectly treated, that the velocity of the wash water is too low, the time of washing too short, the wash water is improperly distributed or sometimes that the rate of operation is excessive. These may be removed by scraping the sand with shovels; or sometimes during washing by skimming them off with a long handled basket of $\frac{1}{4}$ inch wire mesh. On relatively small beds, the sand may be raked during the washing process by long-handled rakes, which break up the balls. Prevention is desirable. Proper pretreatment of the water is most effective.

3. *Mud Layers.*—The presence of mud evenly distributed over the bed after washing, or accumulations of it near the wash water troughs indicate that wash water velocity is too low, washing time too short,

troughs too high, or troughs too far apart.

4. *Cracks.*—Cracks in the sand are usually due to mud being carried into the sand because of insufficient washing; but also due to the presence of clay or other cementing material which binds the sand grains together. A hand rake may be used to break up such areas. Adequate pretreatment of the water will reduce trouble from cracks.

5. *Clogging.*—When mud balls merge or coalesce, large areas of compacted mud may form. This results in uneven loading and operation of the filter, shortened filter runs, and often a poorly filtered water. Adequate pretreatment will reduce or eliminate the cause of such trouble. Deposits can be broken up with water jets, where applicable chemicals can be used, or the sand may be washed.

6. Calcium Carbonate Coating.

When the water contains an excess of calcium carbonate, this may be deposited on the sand grains, which are thus enlarged. Proper treatment of the water is necessary for prevention. For curative treatment, samples of the sand should be tested in the laboratory to determine whether hydrochloric or carbonic acid is the more effective, and the amount required. Dosages required should be determined in the laboratory. Sulphur dioxide is often used, normally employing a solution sufficient in volume to fill the filter, the solution containing 2% by weight of sulphur dioxide.

7. Breaks in the underdrain system or in the gravel layer may result in concentration of wash water into a channel, with mounds of sand forming. Mud balls on the gravel layer may so disturb the flow of wash water as to produce a similar effect.

8. *Removing Organic Matter.*—Shrinkage of sand beds is sometimes due to the cementation of the sand grains by organic matter or gelatinous floc; also at times by fine clay, oil or microorganisms. Most of these can be remedied by treatment with alkali. A 2% or 3% solution by weight of caustic soda, sufficient in volume to fill the bed and cover the sand to a depth of 3 or 4 inches. This, if allowed to stand 12 to 24 hours, will usually give satisfactory results. The outlets of the filter unit should, of course, be closed before the caustic soda is added; after the washing solution is drained off, the bed must be washed thoroughly.

Chlorine also is used, generally in the form of HTH or Perchloron, but also as chloride of lime and liquid chlorine. It is especially effective for destroying algae or slime-producing organisms. A strong solution is prepared, and after the water has been drawn down to about a foot above the top of the sand, this water is dosed to give a strength of about 3,000 ppm. The treated water is then lowered to about an inch above the sand level, thus drawing the chlorinated water into the interstices of the sand; after about 24 hours of contact, the bed is washed thoroughly. Another method is to add chlorine to the wash water and back-wash until there is at least 10 ppm. of chlorine in the water at the top of the bed. Then this chlorine solution stands for 24 hours, after which the bed is washed thoroughly.

9. *Inspection.*—From time to time after washing a

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filter the water should be drawn down below the surface of sand to permit inspection and examination.

10. *Removing Sand.*—Removal of the sand and gravel from the bed is a major operation, and is rarely necessary. Broken or clogged strainers occurring in sufficient number may make sand removal necessary for repair and replacement, but as long as satisfactory bacterial removal and turbidity reduction are obtained the presence of a few defective strainers is not important.

11. *General.*—In some plants that are operated only a part of the day, the filter is washed at the end of each day's run; otherwise, filters are washed whenever the loss of head or decrease in efficiency indicates. There is no set rule for this; as a matter of fact, the various filter units in a given plant may vary somewhat; and there will also be variations from month to month, or even oftener.

There is no substitute for intelligent observation, the keeping of proper records, and a thorough knowledge of conditions at the plant. These form the best basis for good operation. Also there is a large amount of written and recorded experience covering the operation of many plants. The study of this material will reward any operator.

Good results are obtained by careful control of the two principal elements in the filtration process—the preparation of the water by conditioning, coagulation and settling, and the maintenance and proper operation of the filter bed. The proper controls, gauges and operating mechanisms are essential in all but the very smallest and simplest plants.

(d) Slow Sand Filters

1. *The Sand Layer.*—The sand layer is ordinarily 30 to 40 inches deep; beds of fine sand may be shallower than those of coarse sand. The desirable depth is that which will provide the required degree of purification, and will also allow several scrapings or cleanings without reducing the depth of the bed below that which will prove effective. The loss of head is greater with fine sands, and filters built of them require more frequent cleanings.

The effective size of sand should range between 0.2 and 0.3 m.m., and the uniformity coefficient should be between 2.0 and 3.0.

Underneath the sand bed is the gravel layer which surrounds and covers the underdrains. This is 12 to 15 or 18 inches in depth, with coarser stone 1-inch to 3-inch size, at the bottom, and with graded layers of finer stone supporting the sand bed. The underdrain system is built on or in the floor. Floors and walls should be tight and generally are of masonry. Beds vary in size, and may be from $\frac{1}{4}$ to 1 acre, or larger, or smaller. In northern areas, filters are usually covered; operation is difficult when ice forms.

The depth of water normally maintained on the filters is 3 to 4 feet, though in some plants it is greater. This depth is maintained by means of rate-of-flow controllers which regulate the inflow of water to the bed and control the rate of discharge.

The control of the rate of operation is practically the only factor available to the operator of a slow sand filter. The character of the raw water and the period of sedimentation (unless there is excessive capacity in the sedimentation basins) are beyond his control. The maintenance of a proper rate—usually 4 million to 6 million gallons per acre per day—remains the only means of control of the quality of the water, aside from filtration.

Loss of head is the resistance offered by the sand

to the passage of water through it. This is slight at first, but increases as the sand is clogged with material that is strained from the water. When the loss of head reaches several feet, the beds should be cleaned. There is no standard loss of head at which cleaning is considered necessary; it varies from 2 to 6 feet, usually being about 4 or 5 feet. Cleaning may be necessary, depending on the condition of the water at intervals of 2 to 10 weeks.

The total head on the filter, neglecting any friction of the sand, is as follows: Water on the filter 3 to 4 ft.; depth of sand and gravel 4 to 5 ft.; total 7 to 9 ft. In addition, if suction be permitted on the discharge pipe additional "negative head" will be available. Employment of negative head is poor practice as it may result in cracks or breaks in the bed, and also in unsatisfactory treatment of the water.

Cleaning the Sand.—When the loss of head is such that the beds must be cleaned—this varies in different plants but is usually about 4 feet—the water is drained down below the sand level so that men equipped with foot pads can walk on the surface. Using flat shovels, the surface sand is scraped off to a depth of $\frac{1}{4}$ to 1 inch. Removal of the sand may be by an ejector, a conveyor or by wheelbarrows operating on planks.

Sand washers are available for cleaning the sand so it can be used again. These generally use a jet of water and violent agitation for washing.

Cleaning by removal of a thin sand layer is continued until the depth of remaining sand is not less than 24 inches, when 6 to 12 inches of clean sand are added, bringing the beds to the original depth.

Placing a Cleaned Filter in Operation.—The following procedure should be followed in placing slow sand filters in operation after cleaning: Filtered water from other beds or from the mains should be turned slowly into the underdrains of the cleaned bed until the water rises several inches above the sand surface. Raw water can then be turned in but the rate should be such that the sand will not be scoured. Filtration can then be started at a very low rate, gradually increasing over a period of several days—from four days when the filter has been scraped to a week after replacement of sand. During this period, and until tests show the quality of the water to be satisfactory, the effluent from this filter should be wasted.

IX. Disinfection of Water

1. *General.*—None of the steps in water purification—storage, sedimentation, coagulation and filtration—nor all of them combined can be relied on to remove all of the bacteria from the water, though ordinarily only 1% or less may survive these processes in a well operated plant. These remaining bacteria should be removed by disinfection.

Sterilization means that all life is killed; disinfection that all potentially dangerous organisms are killed. Because chlorine and its compounds are almost universally used for this purpose, the term *chlorination* is generally used in waterworks practice.

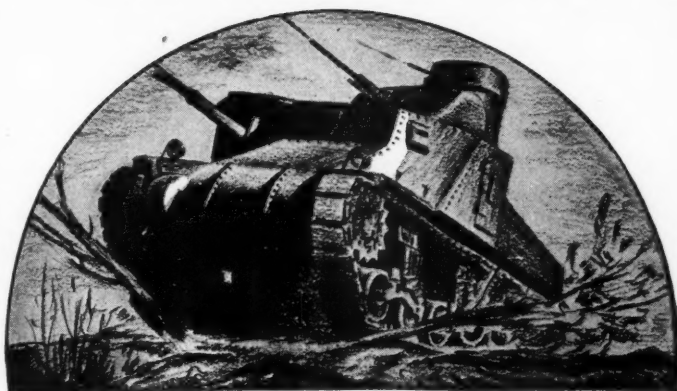
Chlorination is the final safeguard of the quality of the water. As such the necessity for its continuous and regular application in sufficient amounts to accomplish bacterial removal cannot be overemphasized. This requires good equipment; attention, care and intelligence; and the employment of proper tests and checks.

Chlorine is employed primarily in the form of liquid chlorine, and also, especially in the smaller plants, as calcium hypochlorite.

Liquid chlorine is 100% available chlorine. Actually it is a gas, but under pressure it becomes a liquid in

CHLORINE GOES TO WAR

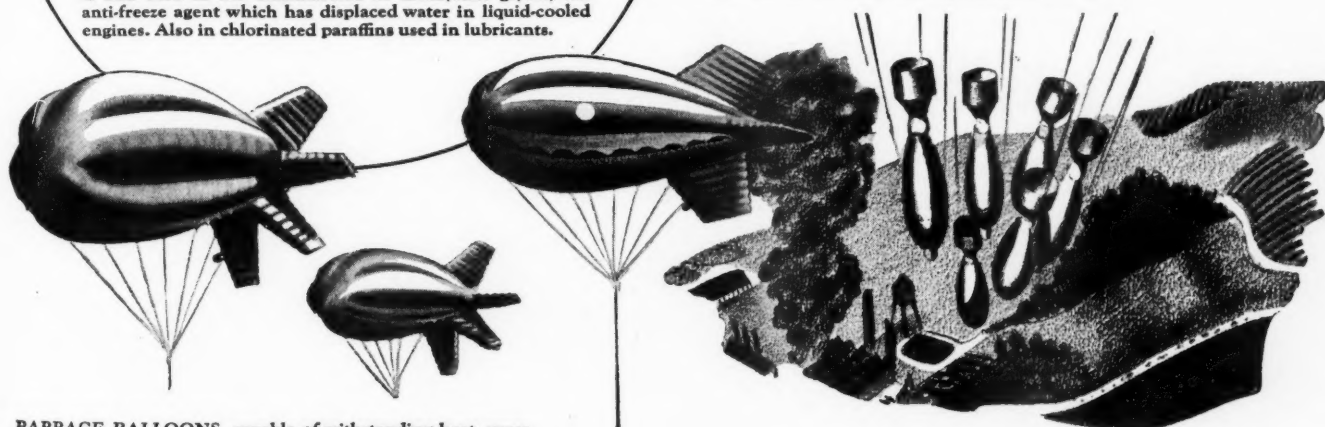
as America mans its battle stations!



HI-OCTANE GASOLINE for U.S. TANKS and PLANES is produced from ordinary gasoline and tetraethyl lead. Rapid precision-fitting of tank and plane parts demands trichlorethylene, a degreasing solvent. Both tetraethyl lead and trichlorethylene require large quantities of chlorine. Chlorine is also used in the manufacture of diethylene glycol, the anti-freeze agent which has displaced water in liquid-cooled engines. Also in chlorinated paraffins used in lubricants.

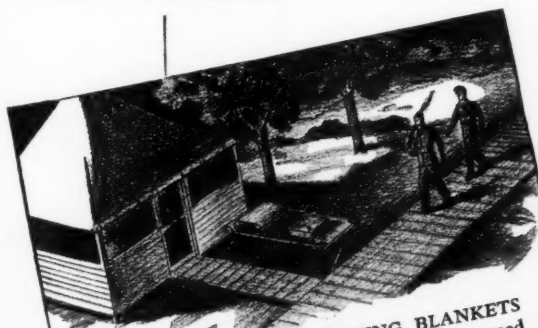


COWLINGS and COCKPIT COVERINGS for AMERICAN WARPLANES are made of plastics derived from chlorine. The now famous degaussing cables, used to protect ships from magnetic mines, are also insulated with these plastics. Another derivative of chlorine is carbon tetrachloride, used extensively in fire extinguishers for tanks, planes and trucks.



BARRAGE BALLOONS, capable of withstanding heat, gases and sunlight, are being manufactured from synthetic rubber. America's fast-growing production of synthetic rubber for protective balloons and other wartime needs has put an extra load upon the chlorine industry.

ALL-OUT PRODUCTION of MUNITIONS requires large amounts of chlorine, especially for processing of cotton linters for smokeless powder and other explosives.



TENTS, UNIFORMS, SHEETING, BLANKETS and **PARACHUTE FABRICS** for the U. S. armed forces are being turned out in millions of units by the textile industry. Thousands of tons of liquid chlorine go into the processing of these vital war materials.



U. S. BASES and ARMY CAMPS require large quantities of chlorine for water purification and sewage treatment. This widespread use of chlorine is in addition to large-scale requirements of state and municipal water works systems.

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which form it is shipped in steel cylinders. The pressure varies with the temperature from 40 to 150 pounds, being greatest at high temperatures. At 70° F, the pressure is about 85 pounds per sq. in. The cylinders most used in waterworks plants contain 100 or 150 pounds of chlorine, but larger and smaller containers are available.

Calcium hypochlorite solutions are prepared from commercial bleach, also called bleaching powder; and from chloride of lime and chlorinated lime. The standard water works calcium hypochlorite powder contains not less than 70% available chlorine and is quite stable. However, when the powder is exposed to the air, moisture will be absorbed from the air and a crust will be formed on the surface. Chlorine will be lost especially at elevated temperatures, and it is, therefore, advisable to keep the container tightly covered. When kept in tight containers, the powder may be stored for a considerable period of time with no appreciable loss of chlorine. The other form available, ordinary chlorinated lime or bleaching powder, containing 25% to 35% available chlorine, is much less stable and loses strength rapidly when exposed to air. When stored in tight containers, the chlorine content is lost more slowly, the rate of loss being around 1% per month.

2. Application of Chlorine to Water.—Improper application of chlorine to the water causes tastes and odors; the use of too little will not insure a safe supply. In small plants an attendant may not be on the job regularly, so that some means for insuring continuous automatic operation must be provided.

The requirements for equipment for applying chlorine to water are accuracy, within close limits, but most of all reliability, for if the application of chlorine fails, an unsafe water may result in serious epidemics.

(a) Liquid Chlorine

1. Liquid chlorine is applied to water by means of a chlorinator. The function of the chlorinator is to take the liquid chlorine from the cylinder, measure it, and feed it in predetermined amounts into the water. Application may be in either of two ways, directly to the medium being treated, as a gas—or first mixed with water and the resulting solution ap-

plied. These two methods are known respectively as "direct feed" and "solution feed."

2. Direct Feed Application.—In a direct feed apparatus, the gas is taken from the cylinder and conveyed through chlorine resistant tubing to the chlorinator. It next passes through a pressure regulating valve, and then to check valve, the function of which is to prevent water from entering the chlorine line when the apparatus is shut down. The gas is applied through some type of diffuser, usually a carborundum stone, which divides the gas into very small bubbles, making it easily absorbed by the water.

The principal difficulty with a direct feed apparatus comes from the plugging of the diffuser by chlorine hydrate or by impurities; diffusion is then seriously impaired, the chlorine gas passes into the water in large bubbles, is not absorbed quickly, and may attack the interior of the piping, valves and fittings, particularly at any high spots in the line.

3. Solution Feed Application.—In this equipment which is the type used in most waterworks plants, the gas is drawn from the cylinder and then dissolved in a small flow of water. The pressure of this water operates an injector which serves to apply the chlorine solution against pressure in the pipe line. In making application against pressure in the pipe lines, various factors such as the type of apparatus being used, the length of hose run from chlorinator to main connection, the height of application point in relation to chlorinator, the amount of chlorine being applied, etc., all enter in fixing the water pressure necessary to operate the injector. A practical minimum ratio is at least 4 to 1, or an increase of 4 pounds in water pressure to the injector for every pound increase in back pressure.

4. Operation of a Chlorinator.—For proper operation, the room in which the chlorinator is kept should be not colder than 50° F. Warm gas entering a colder chlorinator will condense and may cause clogging. Therefore, the chlorinator should not be placed on an outside wall, but should be in a warmer place than the cylinder or the pipe connecting the cylinder and the chlorinator. A radiator, a small stove, or an electric heater may be used. The chlorinator building should be insulated or well protected. When cold is not too intense, an electric light left burning, or a lighted lantern may furnish the required heat.

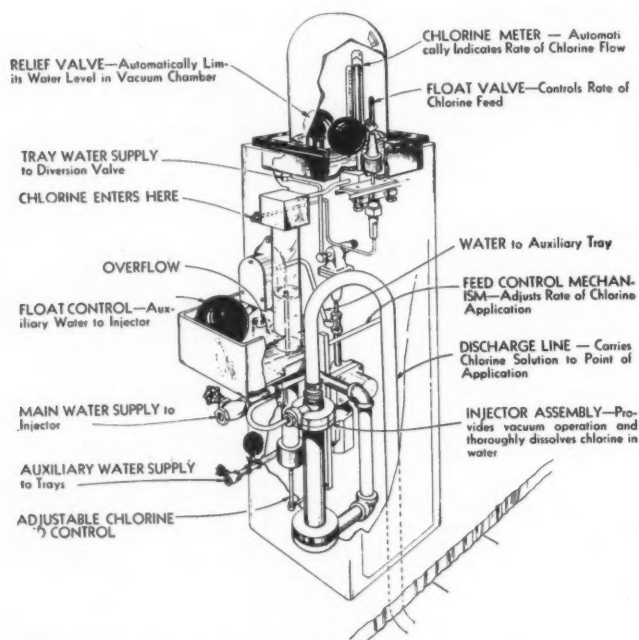
Chlorine cylinders should be kept on scales and the weight read each day as a check against the amount of chlorine used; or in the case of very small plants, the scales should be read every week. Chlorine cylinders should not be exposed to concentrated heat.

The maximum drawoff or discharge from 100 to 150 pound cylinders at 70° F is approximately 35 pounds per 24 hours. Due to the change from a liquid to a gas, an excessive drop in temperature will occur and if more than 35 pounds are used daily, 2 or more cylinders should be attached.

An ample reserve supply of chlorine should be kept on hand; also a reserve supply of duplicate parts, including valves, gaskets, etc. But the operator should not attempt major repairs.

Whenever possible an entire duplicate chlorinator should be kept on hand for possible emergencies. Ask the manufacturer of your chlorinator for full directions for starting and stopping, and for other details regarding it.

Chlorine leaks are, of course, dangerous since the gas is irritant to the lungs and causes violent coughing. A concentration of 1 part of chlorine in 100,000 can be noticed; 1 part to 50,000 parts of air causes

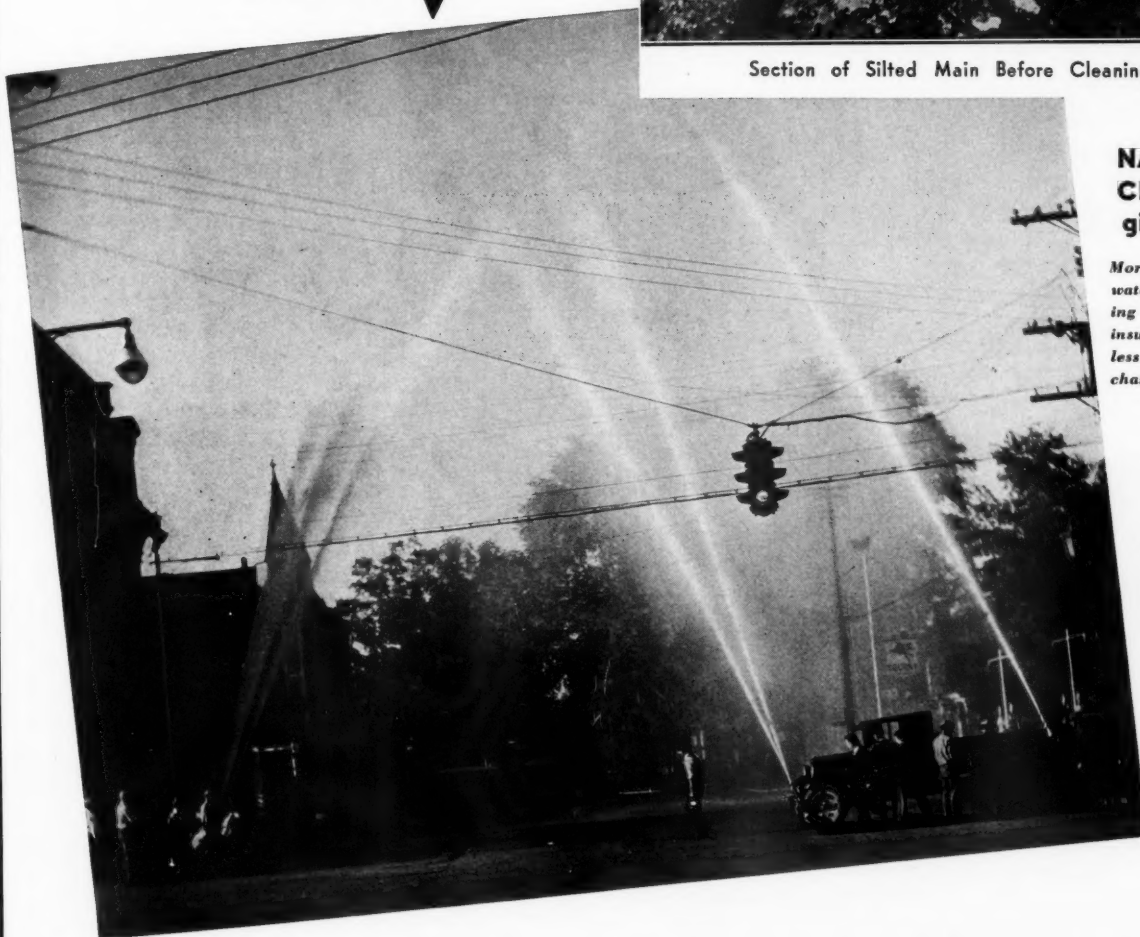


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is neither time nor opportunity to lay new larger mains now. So the task is to get the very maximum out of what you have.

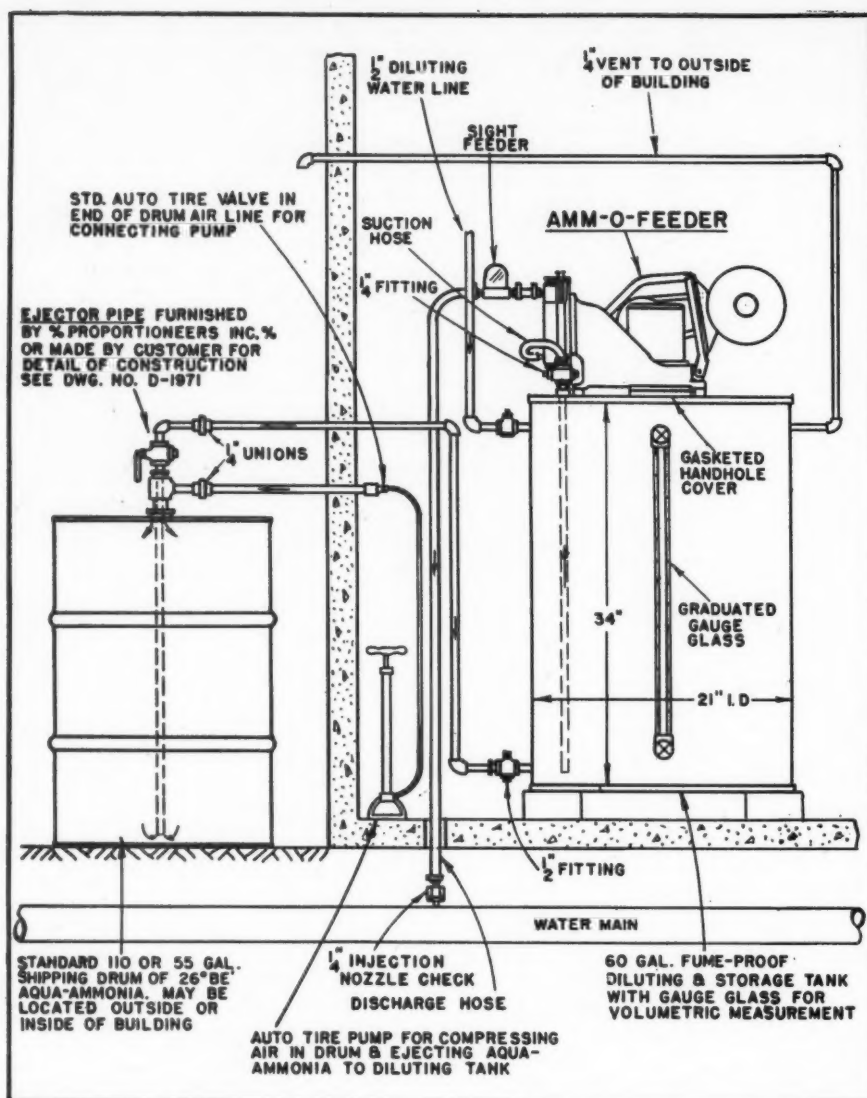
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Layout of Package Amm-O-Feeder, for ammoniation by the fume-proof aqua method for plants up to 25 mgd.

inconvenience; and 1 part in 1000 of air after 5 minutes exposure produces death. Leaks can be located by means of an open bottle of ammonia. Valves, connections and other places that may permit chlorine to escape are tested with the ammonia bottle. White fumes of ammonium chloride are formed when chlorine combines with ammonia. Gas masks are desirable to have on hand for use in case of leaks. Chlorine being heavier than air, ventilation at or near the floor level is desirable.

Metal parts on the chlorinator, or other metal surfaces, become corroded when a gas is present. To prevent this, these may be painted with a thin coating of gasoline and vaseline. The gasoline evaporates and leaves a light coating of vaseline which is sufficient protection.

5. Dosage of Chlorine.—The dosage of chlorine required for making water safe depends on many factors. Waters that are turbid, or contain much organic matter, iron or manganese, may require large amounts. Filtered water, or clear surface water of good quality requires a dosage of 0.2 ppm. to 5 ppm. The chlorine residual test already described is the essential guide to the amount of chlorine required. Most waters are effectively treated when there is 0.1 ppm. to 0.2 ppm. of true residual chlorine present 10 minutes after the chlorine has been applied.

(b) Hypochlorites

1. Hypochlorites are often used in the smaller water plants for chlorination of the supply, and in many plants hypochlorinators are used for standby and emergency work. They are used in the form of a solution of the 70% available chlorine hypochlorite powder or as prepared sodium hypochlorite solution. The 25% to 35% available chlorine bleaching powder or chlorinated lime is now rarely used for this treatment. Ordinary bleaching powder is difficult to feed in the dry form and effective treatment cannot be obtained.

Because of the solubility of the hypochlorite contained in the hypochlorite powder, solution can be made very readily by stirring the desired quantity in water, allowing the mixture to stand and settle. The inert portion of the powder settles to the bottom in the form of a sludge, and the supernatant liquor containing the hypochlorite can be decanted or syphoned off. It is desirable to make up solutions in one container and to feed from another tank containing only the clear liquor. The use of sodium hypochlorite solution as a source of chlorine is, of course, very simple, as it is only necessary to dilute it to the desired strength. While calcium hypochlorite solution should be made up in strengths of preferably not over 3 or 4%, full strength

12½% sodium hypochlorite can be used, if desired.

To make 40 gallons of 1% available chlorine calcium hypochlorite solution, there will be required 40 gallons of water which weighs 333.6 lbs. Chlorine required is 1% of 333.6, or 3.336 lbs. If the calcium hypochlorite powder has a chlorine content of 70%, then 3.336 times 100 over 70 equals 4.76 lbs. of the hypochlorite powder required for 40 gallons of solution. When 12½% sodium hypochlorite is used and a lower concentration is desired, it can be obtained by placing a number of unit volumes of 12½% solution equal to the percentage strength wanted in a container and adding a number of unit volumes of water equal to 12½ minus the number of the final concentration expressed in percentage. Illustration: to make a solution of 1%, place 1 gallon of 12½% solution in a container and add 11½ gallons of water. To obtain a solution of 6%, place 6 gallons of 12½% solution in a container and add 6½ gallons of water.

As solutions lose strength on standing even in dark, cool places, they should not be stored for long periods before using.

2. Hypochlorinators.—Feeding equipment for hypochlorite solutions is available in a variety of forms. The type most used is in the form of a small diaphragm pump capable of manual variation of the stroke length, stroking rate, or both, driven by an electric motor.

This unit can be cross-connected on the starting switch of an electric pump so as to start and stop in step with it, thus providing automatic chlorination, or it can be plugged into an electric light socket and started and stopped manually. Other types are available for operation by water power from the main being treated, and both electric and water operated types can be obtained for control from either Venturi meters or mechanical meters, ranging in size from the $\frac{5}{8}$ -inch house meters up.

3. *Computing Dosages.*—To chlorinate a flow of 500 gallons per minute with a dosage of 4 lbs. of chlorine per million gallons or 0.48 parts per million, using a solution containing 1% available chlorine, the required number of cubic centimeters to be added to the flow per minute is as follows:

4 lbs. of chlorine is contained in 400 lbs. of 1% available chlorine solution. $400 \div 8.34 = 48$ gallons of 1% solution per million gallons. Multiplying the number of gallons required per million gallons of water by the number of cubic centimeters contained in a gallon (3,785), we find that 181,680 cubic centimeters of 1% solution are required per million gallons; or 0.1817 c.c.'s of 1% solution per gallon. Then multiplying the requirement per gallon by the flow rate, 500, we have $500 \times 0.1817 = 90.85$ c.c.'s of 1% solution per minute. (The above factor of 0.1817 cubic centimeters of 1% solution required to treat one gallon with a dosage of 4 lbs. per million or 0.48 parts per million is very convenient and can be used for figuring quantities of chemical for any chemical treatment. Where solution strengths other than 1% are used, it is only necessary to divide by the solution strength in percent.)

As 70% available chlorine calcium hypochlorite is available in 5 lb. cans, a solution made by mixing one 5 lb. can of hypochlorite with 40 gallons of water may be considered as of 1% strength. This is not exact, but is near enough for all *practical* purposes and makes for convenience.

(c) Ammonia Chlorine

When water contains certain industrial wastes, as phenol compounds, the addition of chlorine causes a disagreeable taste; the same trouble may occur if algae are present in considerable quantity in the water.

If ammonia is added to the water just before the chlorine is added, the reaction between the chlorine and the taste-producing organisms is prevented, and much or all of the taste problem is eliminated. The use of ammonia also permits the use of larger doses of chlorine without causing chlorine tastes.

Ammonia should be applied ahead of the chlorine so as to produce a thorough mixing of the ammonia with the water, but not so far ahead that the ammonia is reduced before the chlorine is applied. Generally a few feet is satisfactory.

When ammonia and chlorine are used, the two chemicals combine to form chloramines which do not react as quickly with organic matter as does chlorine alone. Consequently, the rate of disinfection is slower, and a longer period of contact—about 2 hours—is required. Water treated with ammonia and chlorine should not be used, therefore, until 2 hours after treatment. To overcome this, chlorine is sometimes added first in sufficient quantity to sterilize, and then ammonia is added.

An advantage of the use of ammonia with chlorine, is that in small plants, without full-time attendants where the flow or usage of water varies materially from hour to hour, and where the chlorine dosage is

not regulated by automatic equipment in accordance with the volume of flow, the heavier dosages during periods of low flow are less likely to cause tastes when both ammonia and chlorine are used.

Because the ability to disinfect is retained for longer periods, ammonia-chlorine is advantageous for pre-chlorination at filter plants to control algae and slime growths in settling basins and filters.

Ammonia is ordinarily furnished in cylinders of the same type as are used for chlorine; and application is by means of equipment practically the same as that used for applying liquid chlorine. Chlorinators cannot be used since different construction is necessary to prevent corrosion. Ammonia can also be applied in a liquid form by ammoniators of the same general type as the hypo-chlorinators described above.

The dosage of ammonia required depends on the characteristics of the water. Ordinarily it is $\frac{1}{3}$ to $\frac{1}{2}$ of the chlorine dosage. When using ammonia, a higher chlorine dosage is commonly used—sufficient to maintain a residual of about 0.4 ppm.

The use of the orthotolidine test on waters treated with ammonia and chlorine has already been discussed.

(d) Super and De-Chlorination

When phenols are present in the water, small doses of chlorine cause disagreeable tastes; but when a much larger dose is applied—1 to 5 ppm., the tastes are reduced or destroyed. This treatment may cause chlorine tastes, due to the excess chlorine remaining in the water. When this occurs, the water must be dechlorinated, which can be accomplished by adding sodium thiosulphate, sulphur dioxide; sodium bisulphite, activated carbon or blackalum.

(e) Break-point Chlorination

Break-point chlorination is accomplished by adding chlorine to water under controlled conditions until the chlorine demand of the water is completely satisfied. When this point is reached, further addition of chlorine will result in a residual rise almost in proportion to the rate of application. The point just ahead of the rapid rise in residual is known as the break-point; hence, the name. It is at, or just beyond this point, that tastes and odors disappear. The residuals ahead of this point in waters containing appreciable amounts of free ammonia (0.05 ppm. or more) are usually greater than at the break-point. Waters devoid of ammonia will seldom, if ever, produce a dip in the residual curve. In practice, the ratio of chlorine to ammonia necessary to reach the break-point appears to be somewhere in the neighborhood of 10:1, and at the break-point, the free ammonia content will usually be considerably less than where lesser amounts of chlorine are used. Under certain circumstances, where free ammonia is absent, the break-point can be induced to good advantage by the addition of ammonia ahead of the chlorine. When added subsequent to the addition of chlorine at an approximate ratio of 1:10 in relation to the residuals existing at the point of ammonia addition, ammonia assumes the role of a dechlorinating agent.

By the utilization of break-point chlorination it is now feasible to chlorinate to the point that will eliminate more bacteria than has formerly been possible and, at the same time, to produce a water of acceptable quality as regards taste and odor characteristics. The increase in chlorine consumption, in many cases, will be only a few tenths of a part per million greater than under conditions of marginal chlorination, al-

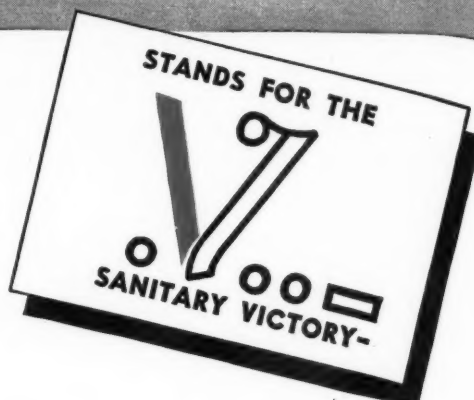


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Much water has been purified in this decade and we are grateful to the Water Works profession which supported our early experimental and development costs; and guided and inspired our efforts. They helped build an engineering, manufacturing, and service organization which has grown to serve our nation in this emergency; and which is trying to maintain its obligations to water works, and which will be 100% at your service after "the duration".



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Our leading the way to low-cost hypochlorination for small plants resulted in general use of methods, machines, chemicals, and price ranges previously thought unattainable.

Unbelievable portability, flexibility, simplicity and standardization of equipment has grown from our early departures from conventional, accepted practice. Mass production of all kinds of Chem-O-Feeders permitted welcome equipment price reduction and consequent wider use of purification apparatus; also better understanding of low-priced, safe technique for water and sewage pollution problems.

Our trade mark stands for "Accurate Percentages" which we proportion on demand in many chemical feeding operations; and for the principle of more chemical feeder per dollar spent! Note that the price of Chlor-O-Feeder has never been raised since the original \$195.00 price was established on Midget Chlor-O-Feeder in 1934. There have been lower priced units developed as demand and mass production allowed hypochlorinators to be sold as low as \$99.00.

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though in other instances it may be necessary to apply several times the usual amount. In either event, the amounts of chlorine involved are usually within the limits of practicability, particularly when the advantages gained are taken into account.

Best results are obtained when the final pH is held between 6.5 and 8.5, and where the time of contact available is a least thirty minutes. Longer times of contact will usually be of material aid. The necessity for pH adjustments will depend on the alkalinity. Low alkalinity waters usually will require more adjustment than those of higher alkaline content. Temperature is of no great importance except that there will be a tendency toward a speeding-up of the reactions as the temperature increases.

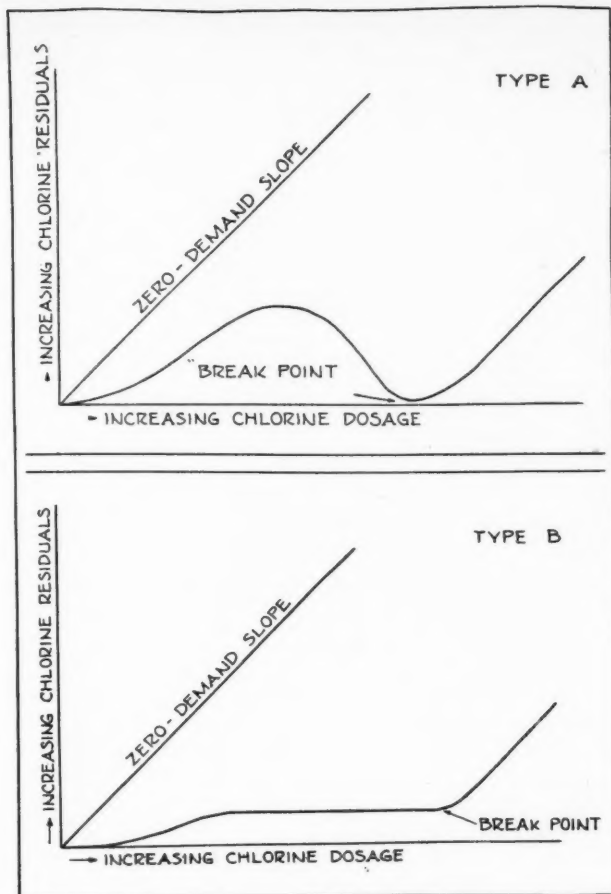
Control of the process must be more precise than the control of simple, or marginal, chlorination. Control in the latter case is usually obtained by making frequent chlorine residual tests augmented by bacteriological analyses. In break-point chlorination, reliance is also placed on the familiar orthotolidine test except that special emphasis is placed upon the speed of the production of the characteristic yellow color. When, upon the addition of orthotolidine, yellow color instantly develops and quickly reaches its full strength, sufficient chlorine has been added to reach, or to pass the break-point. Proper time of contact of chlorine with the water must be allowed before applying this test, however, since almost any water will "flash" within the first few minutes following the addition of chlorine assuming, of course, that any residual is present. This test, developed and used by Laux of Anderson, Ind., is known as the "flash test." The point in the curve where the flash first appears is known as the "flash-point." Where just enough chlorine is added to reach the flash-point, odors will be at their minimum and any that may persist can easily be removed with activated carbon. Treatment with chlorine in lesser amounts than required to reach the flash-point may result in the intensification of tastes and odors, some of which may be exceedingly difficult to remove by any means of dechlorination, including activated carbon. Treatment in this range should be avoided.

(f) Disinfecting Mains and Reservoirs

1. *General.*—Water mains should be protected against contamination while they are being installed; dirt and other material should be removed before laying. Before being placed in service, every section of pipe should be flushed out and then chlorinated, using a dose sufficient to give 50 ppm. of residual chlorine. In some cases, the flushing out is omitted, care being taken to clean the pipe before laying and to prevent contamination from entering during laying. A small amount of bleaching powder, HTH, Hoodchlor, or Perchloron is placed at the time of laying in each pipe, or in the case of small pipe, in each third or fourth length. This method should never be used if the procedure in Par. 2 below can be carried out as is usually possible.

2. When liquid chlorine is used, a corporation cock is inserted in the old line near the point of connection with the new line, and a special stuffing box is inserted and connected to a chlorine cylinder with a silver or copper tube. The stuffing box and tube can be obtained from manufacturers of chlorinators; also special chlorinators for this purpose are available and are preferable.

After the connection is made, the new line is flushed out; after it has drained, water is then turned into it slowly, and chlorine gas from the cylinder is turned



Two types of break point curves.

into the main. Water pressure should normally be below 30 pounds.

A chlorine solution can be used instead of liquid chlorine, in which case it can be forced into the main with a pump or added to the water entering the main.

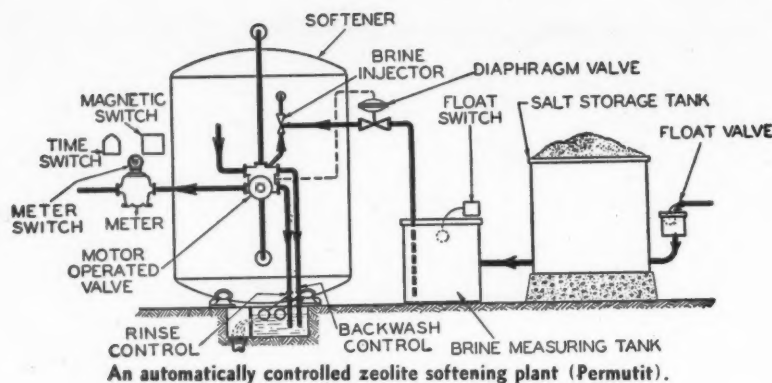
3. When using bleaching powder, 25% available chlorine, the following amounts are required for each 100 feet of pipe:

4-inch, 1½ ounces; 6-inch, 3½ ounces; 8-inch, 6 ounces; 10-inch, 10 ounces; 12-inch, 15 ounces; 16-inch, 36 ounces. When using HTH or Perchloron, 40% as much is sufficient; AWWA Standards suggest 1 pound (70% available chlorine) for each 1680 gallons of pipe capacity to be treated.

When the bleach is placed in the pipes as they are laid, the line is filled slowly with the water and allowed to stand for 12 hours; it is then flushed thoroughly. A serious disadvantage of this method is that the end of the line at which water is admitted is not adequately treated, since most of the bleach is washed to the lower end by the inflow of water.

4. Orthotolidine tests are made on the water as it comes out of the valve or hydrant at the far end of the line. When a deep yellow color is obtained by the test, allow the line to fill, shut off the chlorine, and the valve admitting water to the new line. Allow to stand for 12 hours, and flush thoroughly. If there is no valve or hydrant at the lower end of the line, a testing plug fitted with a stop-cock can be placed in the end of the pipe line, to permit the discharge of air as the line is filled with water, and also to permit taking samples of water for orthotolidine tests.

Filters, elevated tanks, concrete or steel reservoirs, and other similar structures, should also be treated before being placed in service. Liquid chlorine may be



added to the water as these are being filled; $\frac{1}{2}$ to 1 pound of bleaching powder, 25% available chlorine, may be used for 1000 gallons of water. State Boards of Health will furnish detailed directions for procedures in each case.

(g) Safety Measures When Using Chlorine and Ammonia

1. In addition to the precautions already outlined in regard to the use of chlorine, a gas mask should be available in a room not connected to the chlorine or ammonia application or storage rooms. Not all gas masks protect against ammonia. Read carefully the statement on the gas mask canister to be sure that it will protect against both gases. A first aid kit should also be kept readily available.

(h) Potassium Permanganate

1. There has been some use of potassium permanga-

nate for destroying phenols likely to cause tastes; but there is always the possibility that it will, of itself, cause tastes when used in a quantity sufficient to eliminate the phenols; overdoses usually cause objectionable tastes.

This chemical has also been used to oxidize organic matter when this occurs in water in sufficient quantity to materially increase the demand for chlorine. An application of not to exceed 0.2 ppm. will reduce the chlorine demand of water containing much organic matter and generally lessen the possibility of producing chlorinous

tastes by chlorination.

X. How Hard Water Is Softened

1. *General.*—The causes of hardness—calcium and magnesium compounds—have been listed in Section V, Procedure in Testing. In the amounts ordinarily present in water, these chemicals do not affect health, but they interfere with the use of water for many business, domestic and industrial uses. Hardness greatly increases the amount of soap used; reduces the efficiency of hot water heaters and boilers by depositing scale on tubes and heating surfaces; and may hinder the operation of laundries, textile plants and other industrial processes.

Softening is usually effected by one of two processes: The addition of lime and soda ash, which changes the bicarbonates and sulphates of calcium and magnesium from soluble to insoluble forms, and the

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removal of these by sedimentation and filtration; and by passing the water through a bed of zeolite, which transforms the calcium and magnesium salts into sodium compounds which do not cause hardness.

(a) Lime-Soda Softening

1. To soften water by the application of lime and soda ash, the chemicals are added to the water and mixed thoroughly, as with coagulating chemicals; the treated water is allowed to settle, and then filtered. The settling period should be somewhat longer than in filtration; softening can be combined with coagulation and sedimentation, frequently resulting in increased efficiency for the filters, because the precipitate formed by softening is bulky, especially when magnesium compounds are present. Color, when present in sufficient amounts to be troublesome, should be removed before softening, as a rule.

These statements refer primarily to the conventional type of softening plant. In the rapid-rate type of softeners, as the Precipitator and Accelerator, softening reactions are accelerated and mixing, reaction, coagulation and clarification may be accomplished in as short a time as an hour.

2. *Procedure.*—Lime is added to remove carbonate hardness and magnesium; soda ash is used to remove the non-carbonate hardness. Data required are:

Free CO_2 ; half-bound CO_2 which is 44% of the bicarbonate alkalinity; total magnesium; and non-carbonate hardness. These should be expressed in parts per million.

The free and the half-bound CO_2 are added together; 10.62 pounds of pure CaO are required per million gallons to neutralize each part per million of free and half-bound CO_2 .

For instance, if the free CO_2 is 10 ppm. and the methyl orange or erythrosin alkalinity is 150 ppm., CaO required will be:

$$(10 + 150 \times .44) \times 10.62 = 76 \times 10.62 = 810 \text{ lbs. per m.g.}$$

If the lime used is 90% CaO , the amount required will be $810 \div .90 = 900 \text{ lbs. per m.g.}$

The lime required to react with magnesium amounts to 19 pounds of CaO per million gallons per part per million of magnesium. Thus, if the total magnesium amounts to 21 ppm., CaO required will be $21 \times 19 = 399 \text{ lbs. per m.g.}$; and if the lime is 90% CaO , the amount required will be $399 \div .90 = 443 \text{ lbs. per m.g.}$

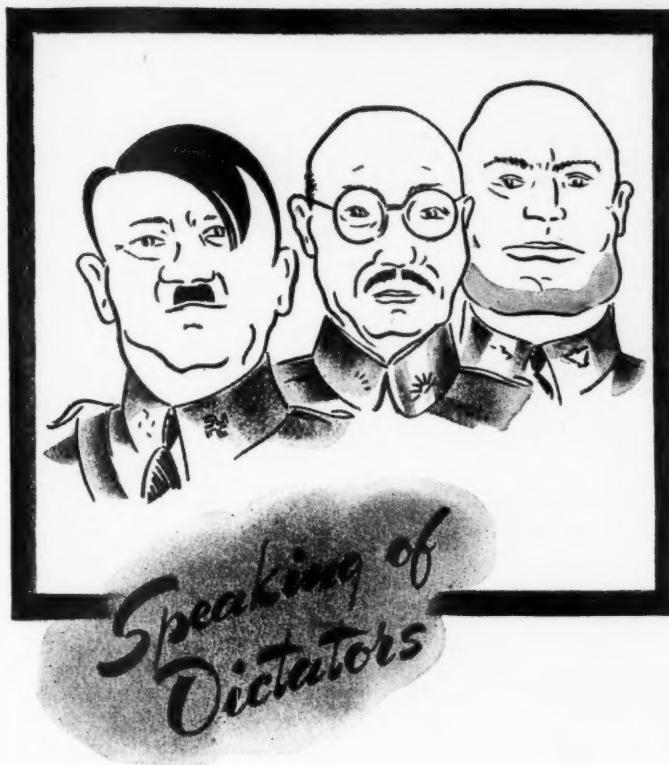
For the removal of non-carbonate hardness, 9 lbs. of soda ash are required per million gallons per part per million of non-carbonate hardness, expressed as CaCO_3 . Thus, if the non-carbonate hardness is 95 ppm., the amount of 100% soda ash required will be $95 \times 9 = 855 \text{ lbs. per m.g.}$

It is usual to leave a carbonate hardness of 35 ppm. to 50 ppm. and a total hardness of 50 to 100 ppm. In practice this amount should be subtracted before computing the chemical dosage. For instance, if the non-carbonate hardness is 95 ppm., and it is desired that the treated water should contain 50 ppm. of non-carbonate hardness, the soda ash required will be:

$$(95 - 50) \times 9 = 405 \text{ lbs. per m.g.}$$

Jar tests, already described, may be used to check the calculations of lime and soda ash.

3. *Recarbonation.*—When water is softened with lime, some of the carbonates may remain in suspension in the water, and precipitate on the sand grains of the filter or in the piping of the distribution system. This is especially the case when the excess lime treatment



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is used, which consists of overdosing the water with lime—35 to 50 ppm. excess of lime—resulting in a very rapid formation of flocculent matter.

This excess dosage of lime results in a caustic alkalinity. This can be remedied by the addition of soda ash, converting the excess calcium hydroxide to caustic soda; but this may cause foaming in boilers; and does not improve the taste of the water.

The addition of carbon dioxide will remove the caustic alkalinity by changing the calcium hydroxide to calcium carbonate. This is known as recarbonation.

The CO₂ for the small plant is generally produced by burning gas, oil, coke or coal; stack or produce gases can be used. For burning oil, gas or coke, a small stove may be used, the gas from which contains about 10% of CO₂. This gas must pass through a washer, a drier, a trap for further removal of the moisture and a compressor or blower, which forces it through a grid or diffuser into the water. Porous diffuser plates reduce the required depth of basins and the power cost of CO₂ diffusion.

The theoretical amount of CO₂ required in pounds per million gallons is 3.7 times the parts per million of calcium carbonate; in practice 25% should be added to this. A plant with a capacity of 1 m.g.d. will ordinarily not require more than about 500 pounds of CO₂ daily or about 30 cubic feet per minute of gas. A discussion of this subject is given in Water Supply and Treatment, by Charles P. Hoover, published by the National Lime Association.

(b) Zeolite Softening

1. *General.*—Zeolites are mineral compounds which have the ability when water is passed through them, to remove the hardness. In reality this is an exchange. The zeolites normally have a sodium base, but when water containing calcium and magnesium is passed through the zeolites, the sodium is given up and its place is taken by the calcium and magnesium which are taken from the water. When all the sodium has been replaced by calcium and magnesium, the zeolite must be regenerated, which is accomplished by passing a strong salt solution through it. The calcium and magnesium are then exchanged for sodium and the bed of zeolite is again ready for softening water. This process is continued indefinitely.

The zeolite generally used resembles a green or whitish sand, though the black carbonaceous zeolites are increasing in use. The zeolite is usually placed in a steel tank similar to and operating like a pressure filter. The bed of zeolite is placed on a layer of gravel underneath which is the drainage system or on a system of porous plates, which eliminate the need for gravel. The bed of zeolite is usually 30 to 60 inches thick. The washing system is generally the same as in a rapid sand filter, though the rate of wash is usually lower—from 6 to 8 gallons per square foot per minute.

2. *Operation.*—The rate of operation is greater than with rapid sand filters—ordinarily 4 to 6 gallons per square foot per minute. The zeolite is not intended to act as a filter, nor to remove suspended matter from the water. Consequently only clear water should be passed through the zeolite, and in the case of filter plants, softening will normally follow filtration.

The rock salt for regenerating the zeolite is made into a brine. As applied to the zeolite for regenerating, the brine should contain not more than 10% nor less than 5% of salt.

In regenerating, the incoming water is shut off, the outlet closed, the unit backwashed, and the brine in-

roduced. It is either held in contact for 10 to 15 minutes or circulated slowly through the bed.

After regeneration, the beds are put back into service. Sometimes the water is wasted until the effluent shows a hardness of about 17 ppm.

Zeolites will soften water to zero hardness, but this is not often desirable, and a hardness of 50 to 70 ppm. is generally permitted. This is usually accomplished by softening completely a part of the water and mixing this softened water with enough raw water to obtain the desired results.

Occasional tests are made on the water to determine when the zeolite is losing its ability to remove hardness. The soap test is frequently used for this purpose.

Zeolites will also remove iron and manganese. This will be discussed in the section on iron and manganese removal.

XI. Algae Identification and Control

1. *General*.—Plant growths of the algae type may create trouble by causing tastes and odors, by giving the water a colored appearance, and by tending to clog filters or other treatment processes. In addition, other microscopic organisms in water may contribute to these troubles or cause some all their own.

The microscopic organisms in water include the algae and fungi, which are plants; and the protozoa, rotifera, crustacea and vermes, which are animals.

The term *plankton* is often used to designate the above organisms. Strictly speaking, the term refers to organisms that float free in the water, but it has been extended to include those organisms, exclusive of bacteria, that are found in the open waters of lakes and streams.

2. *Algae*.—There are six commonly recognized classes of algae: Cyanophyceae, or blue green; chlorophyceae, or green; xanthophyceae, or yellow green; diatomaceae, or diatoms, usually brown; the phaeophyceae, or brown; and the rhodophyceae or red. Each of these classes are still further subdivided.

Because of the presence of Chlorophyll in the organisms, only sunlight and carbon dioxide are necessary for the growth of algae in water. Such growths are most prevalent during warm weather. Therefore, as the temperature of the water increases in the early summer, frequent examinations of the water should be made so that preventive treatment can be instituted before the growths have become sufficiently numerous to be troublesome.

It is desirable that such treatment be based on actual knowledge of algae growth conditions. This is best obtained by a microscopical examination to determine the kind and number of organisms in the water. With such knowledge, treatment may begin as needed; but if facilities for this examination are lacking, algae control, in the northern part of the United States, should generally start about May 1 and continue till nearly Nov. 1.

3. *Microscopical Examinations for Algae Growths*.—A sample of about two liters of the water should be taken, using a clean container, from a point where the organisms will be as representative as possible. The container should be inserted with the neck downwards about a foot below the surface of the water, then inverted and allowed to fill. For greater depths, special sampling devices are necessary. The sample should be examined within 6 to 8 hours; if this is not possible, it should be preserved by adding 20 ml. of formalin for each liter of water in the sample.

If the sample of water contains a large number of organisms, it can be examined microscopically without

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concentration. If the number of organisms is small, the sample should be concentrated by filtering or centrifuging. The Sedgewick-Rafter method of concentration is simple and inexpensive. The process is as follows:

A Sedgewick-Rafter funnel of 500 ml. capacity is fitted at the bottom with a $\frac{1}{2}$ -inch one-hole rubber stopper. A small glass U-tube is inserted in the stopper so that the outer arm extends 1 inch above the small end of the stopper. A $\frac{3}{8}$ -inch diameter cloth disc, preferably of silk bolting cloth, is then inserted, so that it lies flat on the rubber stopper. White sand of 60 to 120 mesh is then poured into the funnel to a depth of $\frac{1}{2}$ inch; 5 to 10 ml. of distilled water is then used to wash down any sand adhering to the walls of the funnel and to drive the air out of the sand. The entire device can be purchased ready for use.

The sample to be concentrated is mixed by gentle agitation and 250 to 1,000 ml. is accurately measured out for concentration. The size of this portion depends upon the number of the organisms in the sample. The funnel should be held in a slanting position, the measured sample of water poured slowly into the funnel, and allowed to filter through the sand. If necessary, moderate suction may be employed. Occasionally during the period of filtration the sides of the filter should be washed down with distilled water. When the water has reached the level of the U-tube, this tube is removed to allow most of the remaining water to drain through the sand.

The rubber stopper is then removed and the sand transferred to a small beaker. The walls of the funnel are washed with 5 ml., 10 ml., or more of distilled water. This washwater should be collected in the beaker containing the sand. The water and sand are

well, but not violently, mixed and after a moment for settling, the water is decanted immediately into a beaker.

This concentrate is mixed by a rotary motion and one ml. is transferred to a counting cell. The cover glass should then be slid into position so that the entire cell is covered. After allowing this cell to stand for a few minutes, it is placed under the microscope for examination.

The microscope should be capable of magnification of from 60 to 400. The degree of magnification used depends upon the type of organisms present and whether the organisms are being counted or identified. In the examination of the larger organisms a 48 mm. objective is used. For the counting of small organisms and identification of different types, a 16 mm. objective is used in order to obtain the higher magnification.

For counting the organisms, the cell employed is such that the depth of the sample under examination is 1 mm. The proper magnification should be such that the stage covered by the micrometer is exactly one square millimeter; and since in the standard field each cell covers $1/1000$ mm. of the sample or concentrate, by counting the total organisms in 10 fields, $1/100$ mm. of the sample or concentrate will be covered. The 10 fields counted should be well distributed. The total micro-organism count in a sample is recorded as the number of standard units per ml. without regard to the type present.

The cost for the minimum of equipment needed for this work is less than \$75. Methods for microscopical examination of water are covered in greater detail in *Standard Methods of Water Analysis*. The identification of algae types requires considerable experience

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Copper Sulphate Required for Treatment of Microorganisms*

Organism	Odor	PPM.	Lbs. per M.G.
Asterionella	Aromatic, geranium, fishy	0.12-0.20	1.0- 1.7
Synedra	Earthy	0.36-0.50	3.0- 4.2
Tabellaria	Aromatic, geranium, fishy	0.12-0.50	1.0- 4.2
Eudornia	Faintly fishy	10.0	83.2
Hydrodictyon	Very offensive	0.10	0.8
Pandorina	Faintly fishy	10.00	83.0
Volvox	Fishy	0.25	2.1
Anabaena	Moldy, grassy, vile	0.12	1.0
Aphanizomenon	Moldy, grassy, vile	0.12-0.50	1.0- 4.2
Clathrocystis	Sweet, grassy, vile	0.12-0.25	1.0- 2.1
Coelosphaerium	Sweet, grassy	0.20-0.33	1.7- 2.8
Cylindrospermum	Grassy	0.12	1.0
Ceratium	Vile	0.33	2.8
Cryptomonas	Candied violets	0.50	4.2
Dinobryon	Aromatic, violets, fishy	0.18	1.5
Glenodinium	Fishy	0.50	4.2
Mallomonas	Aromatic, violets, fishy	0.50	4.2
Peridinium	Fishy, like clam shells	0.50-2.00	4.2-16.6
Synura	Cucumber, muskmelon, fishy, bitter	0.12-0.25	1.0- 2.1
Uroglena	Fishy, oily, cod liver oil	0.50-0.20	0.4- 1.6
Beggiatoa	Very offensive, decayed	5.00	41.5
Crenothrix	Very offensive, decayed	0.33-0.50	2.8- 4.2
Sphaerotilis natans	Very offensive, decayed	0.40	3.3

and at first will require reference to illustrations of the various types. A complete treatment, and a large number of illustrations will be found in *Microscopy of Drinking Water* by Fair & Whipple.

(a) Copper Sulphate Treatment

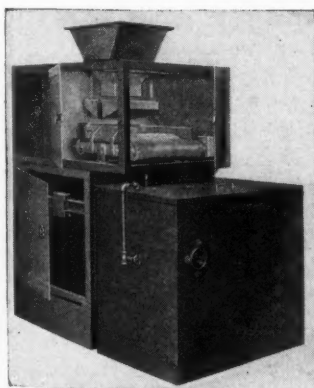
1. Prevention or control of algae is necessary in both storage and distributing reservoirs. Growths may be killed by the use of copper sulphate or chlorine. The latter, while easy to apply within a treatment plant,

is quite difficult to apply in reservoirs, consequently copper sulphate is almost universally used for algae control in these. In the table herewith the more troublesome algae types are listed, with their odor characteristics, and the amount of copper sulphate required for treatment.

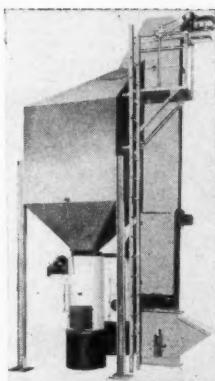
A proper dosage of copper sulphate should be applied as insufficient dosages are ineffective. A concentration sufficiently high to be injurious to health would

*Hale, Frank E., "The Use of Copper Sulphate in Control of Microscopic Organisms," Nichols Copper Co., New York.

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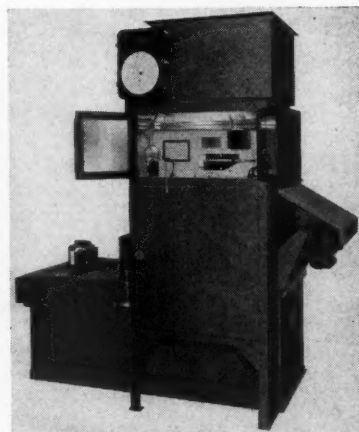


Left—Belt Gravimetric Feeder weighs material as it is fed on a short section of conveyor belt which is mounted on accurate scales. Feeding range may be from 5 to 3,000 pounds per hour. Standard feeders have faulty operation alarms and totalizers to show number of pounds fed.

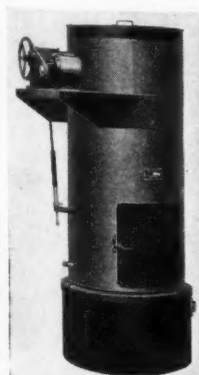


Above—Combined Bucket Elevator, Storage Hopper Chemical Feeders, and Dust Filter—designed and built by Omega. The Feeders shown are No. 2 Omega Universals. Storage capacity 12 tons. Bucket elevator may be arranged for filling from truck or railroad car or placed in a separate room.

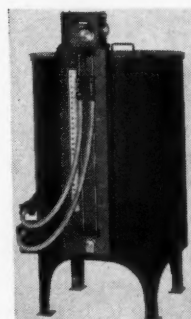
Right—Size No. 1 Gravimetric Feeder with 2,000 lb. hopper and mechanical operation recorder, mounted over a Lime Slaker. The entire hopper load of chemical is carried on scales, which control the rate of feed. Slaker sizes 175 to 6,000 lbs. per hour.



Right—Precision Feeder for solutions or light suspensions. Feeding capacities range from 1/25 to 400 gallons per hour. Electric or spring motor drive. Tanks may be equipped with dissolving baskets and agitators for dissolving lump material. For Hypochlorite—Ammonia—Ferric Chloride, Calcium, Etc.



Left—Universal Feeder for powdered or lump material (1" screen). Built in three sizes with rates of feeds from 1 to 6,000 lbs. per hour. Especially designed for use with extension hoppers or overhead bins. Rugged, accurate, dependable. In use over twelve years.



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have such a disagreeable taste that it would be practically impossible to drink it. However, the dosage necessary for control of algae may be sufficient to kill fish. Therefore, if fish are present in the water to be treated, it is advisable to consult the table herewith which shows the resistance of various species of fish.

Dosage of Copper Sulphate Likely to Kill Fish*

Fish	Parts per Million	Pounds per Million Gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickrel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.36	11.1
Black Bass	2.00	16.6

2. *Application of Copper Sulphate.*—The most common procedure is to place the copper sulphate crystals in bags which are then dragged behind boats. In some cases perforated metal boxes or buckets have been utilized in place of bags as containers for the copper sulphate. Where the body of water is too shallow to allow ready access by boat to the affected areas, or is very small, a bag of copper sulphate may be suspended in the center of an inflated innertube and dragged around over the surface of the water with a rope attached to the tube.

Since algae growths are more profuse in shallow areas, all of these areas should be reached by the treatment. This can be accomplished by zig-zagging the boat back and forth, gridironing, or otherwise so routing the boat that the paths of travel are 20 to 100 feet apart.

The continuous application of copper sulphate to reservoirs during the warmer months, as a concentrated solution to the water entering the reservoir, has been successful in preventing growth. A relatively small dosage is usually sufficient.

XII. Methods of Taste and Odor Control

1. *General.*—Tastes and odors do not cause disease and rarely indicate dangerous contamination. But when they render a supply unpalatable, the consumer is likely to turn to other supplies, often less safe, as wells, springs or bottled water. To protect the health of the community by furnishing a safe and a palatable water at all times is the duty of the water official. It is also good business.

2. *Sources of Tastes and Odors.*—The most common sources of tastes and odors in water supplies are plant growths of the algae type. Some of these organisms exude oils or decomposition products which impart a disagreeable taste to the water, especially in combination with chlorine. Decaying vegetation, as leaves, grass and moss, is often a contributing cause. This cause is particularly evident when reservoirs are low, and contain swampy or stagnant areas.

Severe and troublesome taste and odor conditions are often due to industrial wastes from coke plants, chemical plants, canneries, tanneries, oil refineries, and dairies.

3. *Methods of Control.*—The prevention of tastes and odors in the water may be accomplished by preventing the formation or growth of substances that may cause taste, as in the case of algae; by preventing the entrance of industrial wastes into the supply; by neutralizing or destroying the taste and odor-producing

substances; or by removing them. Local conditions will usually determine which of these methods or combinations of them will be most effective and economical.

4. *Preventive Measures in Raw Water.*—Every measure possible should be taken to eliminate at the source all conditions tending to cause tastes and odors. An early step, as already stated, should be a complete and thorough survey of the entire watershed to determine the points where pollution may originate. See PUBLIC WORKS, Aug., 1941, pages 17-38.

Preventing the entrance of industrial wastes into the supply is not always practical, since the expense of treatment may be too great. The waste causing the trouble, which may be only a small part of the total waste produced, can often be treated or disposed of separately; or even stored and discharged during high water periods.

Swampy and stagnant areas should be eliminated as far as possible, since decaying vegetation and leaves may contribute high color as well as disagreeable tastes and odors. In eliminating these, the better procedure is to either fill or deepen them; to arrange for proper drainage; to build channels to carry the fresh water around or through the affected areas; or the stagnant water may be cut off by means of dykes or other embankments.

5. *Preventive Measures in the Distribution System.*—Bacterial slime growths sometimes accumulate in the pipes, causing tastes and odors. The maintenance of an effective chlorine residual will keep such growths in check and often prevent tastes and odors from these causes.

6. *Corrective Treatments.*—Preventive measures are not always effective or possible. When they are not, corrective measures must be used. These include the following: Aeration; prechlorination; superchlorination; break-point chlorination; potassium permanganate; and activated carbon.

Tastes due to necessary heavy chlorine applications, and their prevention by the use of ammonia, or by super and dechlorination have been considered previously; also the use of potassium permanganate.

(a) *Aeration.*—By exposing a large surface area of the water to air, aeration liberates such gases as hydrogen sulphide and carbon dioxide from the water and permits the oxygen in the air to come in more intimate contact with the finely divided water particles, thus increasing the dissolved oxygen content of the water. This increase of oxygen content tends to remove the offensive tastes and odors by oxidation. Aeration has other uses also, as oxidation of iron and manganese. However, aeration is not very effective in reducing CO₂ content below 3.0 to 5.0 ppm.

The general types of aerators in use include: (1) The cascade type, where the water is allowed to flow over successive sets of weirs in a step arrangement or past baffles set in the path of the water so that the direction of water flow is continually being changed, the water being agitated meanwhile; (2) The diffusion method, which consists of blowing air under a slight pressure through porous plates which are so constructed that a flow of small air bubbles rises through the water continually. (3) The spray method, in which the water is discharged under pressure through nozzles so that the water is forced into the air in a fine spray. This is the most commonly used method; (4) The surface contact type, which consists of coke-filled trays through which the water is passed.

Aeration affects only a few of the taste-producing elements. It should be used only after analyses and investigations of the water have shown clearly that

*Moore, G. T., and Kellerman, K. F. Bul. No. 76, Bur. Plant Indus. U. S. Dept. of Agri. (1905).

aeration will be effective under the conditions that actually exist. A recent development is a combination of aeration and activated carbon, which appears effective in odor reduction.

(b) *Activated Carbon.*—(1) *General.*—Activated carbon may be used in either powdered or granular form. In industrial and a few municipal plants, the water is passed through a bed of granular carbon. In the majority of municipal plants, the powdered form is utilized, the carbon being applied by means of dry feed machines, solution feed machines or mixed with other chemicals. In dry feeding, equipment specifically designed for this material should be used, since activated carbons are much lighter and finer than other chemicals commonly employed in water treatment. Important factors in dry feed equipment are:

Sufficient agitation in the hopper to insure a constant flow to the feeding control mechanism. Design of solution pot so that intimate and violent mixing of the carbon with the water is obtainable. Use of a water ejector to carry flow from solution pot. The lines beyond the water ejector should be straight to eliminate back pressure and deposition of the carbon in the lines. Rubber hose has been found effective since the flows are fairly uniform and deposits of the carbon can be broken loose by a sharp blow on the hose.

Activated carbons are not soluble in water, but solution methods can be used, the particles being carried in suspension to the point of application. Thorough agitation is necessary, since it is difficult to completely wet the carbon particles. The solution tank should be equipped with an agitator for mixing to prevent the carbon particles from settling. Orifice feed methods are not satisfactory, as there is occasional stoppage of the orifice. A siphon arrangement is better.

Activated carbon may be mixed and fed with alum or lime in the same dry feed machine, and such a prepared mixture (Black Alum) is available. Activated carbon should not be mixed with hypochlorite or other chlorinous compounds or with permanganate, as the result may be a fire or explosion.

(2) *Points of Application.*—Where filter plants are a part of the purification process, activated carbon is applied at any point prior to the filters. It may be applied as a thin, watery slurry directly on top of the filters, to the filter influent, part way through the coagulation basin, at the entrance to the coagulation basin, in the mixing basins, or to the raw water. In general the points of application are divided into two general classifications, namely, prior to coagulation, and following coagulation.

In any case the points where the carbon is to be applied should be such that thorough mixing is assured so that the carbon will be properly distributed throughout the body of water to obtain as intimate a contact as possible of the carbon particles with the taste and odor producing substances present. For example, if it is found that the most effective results are accomplished by application prior to coagulation, the carbon may be applied at the suction side of the pump, as in passing through the pump thorough mixing of the carbon particles with the water is insured.

If applied after coagulation the activated carbon will have the least work to do, since there is usually some elimination of tastes and odors during the sedimentation process. This point of application is recommended: (1) where tastes and odors are of short duration; (2) where tastes and odors appear suddenly and have not been noted until they have penetrated fairly well through the plant; (3) where tastes and odors are very mild.

For WAR EMERGENCIES

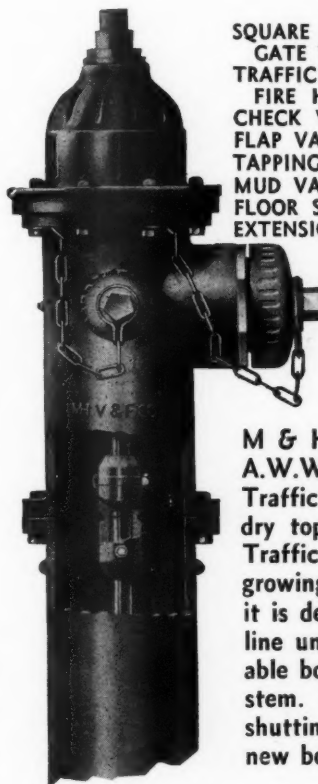


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M & H furnishes both regular type A.W.W.A. fire hydrants and special Traffic Model—all compression type, dry top and revolving head. Special Traffic Model (shown at left) is growing rapidly in popularity because it is designed to yield at the ground line under impact, due to its breakable bolts and breakable coupling on stem. Repair then is easy without shutting off pressure. Simply install new bolts and coupling.

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Application prior to coagulation insures a longer contact time for the carbon to do its work and to accomplish other incidental benefits. This point of application appears to be most suitable for the following: (1) where tastes and odors occur continually or frequently; (2) where the organic content of the water is relatively high and may cause tastes and odors due to decomposition within the plant itself; (3) where tastes and odors are of a severe nature, requiring heavy dosages of activated carbon. A split treatment may be preferable for serious tastes.

Incidental benefits may include: better coagulation, better control of coagulation, greater uniformity in chlorine demand of the water, stabilization of sludge in the sedimentation basin, longer intervals between cleanings of the sedimentation basin and longer filter runs.

(3) *Dosages of Activated Carbon.*—The required dosages of activated carbon have varied from as low as 1 lb. per million gallons to as high as 1000 or more lbs. per million gallons. However, calculations based on a survey reported in the March, April and May, 1936, issues of PUBLIC WORKS indicates that the average dosage being employed is approximately 16 lbs. per million gallons.

(4) *Application to Reservoirs.*—Activated carbon in the powdered form can be applied to reservoirs, the only requirements being that the reservoir so treated be taken out of service for a period of preferably 48 hours. The method of application consists of first mixing the carbon thoroughly with water in a suitable container, such as a drum, and then scattering the suspension of carbon slurry over the surface of the reservoir from a boat. The carbon suspension should be so applied that as uniform a dosage as possible is applied to all of the water in the reservoir. In other words, more carbon should be applied at the deeper sections than is applied in the shallow areas. Better settling of the carbon is obtained if the application follows within a day or so a copper sulphate treatment of the reservoir. The objection to the application of activated carbon to a reservoir which is kept in service is that the small particles of activated carbon will get into the distribution system. This may result in complaints on the appearance of the water for a day or so, but is not harmful in any way to the consumers.

(5) *Granular Activated Carbon Filters.*—Activated carbon in the granular form is also used in pressure filters. This type of treatment is particularly suited to small water systems, industrial plants, and small municipal installations.

XIII. Iron and Manganese Removal

The presence of iron in the amount of 0.3 or more ppm. is shown by rusty or brown stains on plumbing fixtures, and also by stains on articles washed in the water. Growths of crenothrix, or iron bacteria, may occur in the pipes of the distribution system. Manganese produces generally similar effects.

The principal methods of removal are by oxidation or by passing through zeolites; other methods include aeration; treatment with lime and alum or ferric sulphate, passage through contact beds of broken stone, coke, etc., and filtration—preferably through rapid sand filters preceded by coagulation and sedimentation, which aid in removal.

Iron is usually present as ferrous bicarbonate ($\text{Fe}(\text{HCO}_3)_2$) or ferrous hydroxide ($\text{Fe}(\text{OH})_2$), and manganese as manganese hydroxide ($\text{Mn}(\text{OH})_2$) or sulphate (MnSO_4) or as the chloride (MnCl_2).

Various aerating devices have been mentioned in connection with treatment for taste and odor removal. Blowing air through porous plates, spraying into the air by means of nozzles, or the use of trays, steps or pans so that the water falls over these in thin sheets, are most commonly used. Air lift pumps commonly provide sufficient air when these are used in handling the water. And since only a small amount of oxygen is needed when there is no CO_2 present—about one-seventh the amount of iron present—this can sometimes be provided by admitting this into the suction of the pump through a "sniffer." With appreciable amounts of CO_2 present, this cannot be done.

The effect of aeration is to render the iron insoluble, in which form it can be removed in part by sedimentation and wholly by filtration.

Manganese, under some conditions, will not oxidize as readily as iron, and when present with iron may interfere with removal of that element by aeration.

In acid waters, iron and manganese may require the addition of enough lime to raise the pH above 8 or 9 before aeration.

The ordinary zeolites used for softening water remove soluble iron and manganese simultaneously with hardness, and will even continue to remove them for a time after their capacity to remove hardness fails. Special zeolites are also provided, as manganese zeolite, which is a sodium zeolite converted by manganous chloride to manganous zeolite; sodium or potassium permanganate is used for regeneration.

Insoluble forms of iron or manganese will tend to clog the zeolite; therefore iron-bearing water should not be aerated before passing through the zeolite, unless filtration is also provided; and well waters containing iron should pass directly to the zeolite without exposure to air. When an air-lift pump is used on such waters, a period of sedimentation prior to treatment by zeolite should be provided. When the raw water contains any considerable amount of iron, it is good practice to remove the iron (usually by aeration and filtration) before passing the water through the zeolite.

As already stated, where zeolite softeners are employed, a part of the water only is softened and this is mixed with the unsoftened water to produce water of the desired hardness. When this is done, the portion of the water that is not softened can be passed through manganese zeolite to remove the iron and manganese.

XIV—Corrosion Control

Prevention of corrosion of pipes and other metal objects has for years been attempted by maintaining the water at the optimum pH. Recently many water works have had good success with applying sodium silicate in dosages just sufficient to deposit and maintain on the exposed surfaces a thin film of metallic silicate similar to a thin film of glass, thus preventing contact of the corrosive water with the metal.

Lime or other alkaline chemicals are often applied to the water for controlling corrosion. This sometime results in excessive deposition of calcium carbonate on pipes, filter sand, etc.; as has also the pumping of an unstabilized lime-soda softened effluent. By feeding approximately 2 ppm of sodium hexametaphosphate (sold under the trade name of 'Calgon'), there is formed on the surfaces a film of metallic phosphate, molecular in thickness, which protects them from corrosion. This, called "threshold treatment," also stabilizes highly saturated solutions of calcium carbonate, preventing scale formation on pipes, filter sand, in boilers, etc.

Terre Haute Constructs Sewer by Tunneling To Avoid Inconvenience to the Public

(Continued from page 16)

Personnel.—The construction of this work was under the direction of the author; the lines and grades were taken care of by Paul Meadows, Assistant Engineer; the City Inspector was George Withrow. This is a W.P.A. project sponsored by the City, and the W.P.A. duties were ably carried on by Raymond Pike, State Director, C. Harold Page, Area Supervisor, and Tim O'Leary, Superintendent of Construction.

Although this work was carried on by men inexperienced in tunneling, very satisfactory results have been obtained. No accidents of any kind have occurred and progress has been very good. Progress has averaged about 3 feet per eight-hour shift, or from 9 to 10 lineal feet for three shifts in twenty-four hours. With four header gangs working, we were able to make from 30 to 40 feet per day. No serious difficulties in excavation were encountered and no water troubles. Before the start of the work our engineer, superintendent, foreman, and inspector spent some time in Indianapolis where a similar tunnel was in progress, and obtained information which gave us our start; and with that and the help given us by A. W. Spaulding of Middletown, Ohio; Tom Goby of W. Q. O'Neill Company of Crawfordsville, Indiana, representatives of the Armco Liner Plate; and T. L. White, of the Commercial Shearing and Stamping Company, we got under way and have completed a very satisfactory tunnel, built with local labor and local supervision, of which we feel very proud. We invite all persons interested in this

type of work to visit us, so that we can show what we are doing and how we are doing it.

Good Road Foundations Out of Bad

In one locality the recent winter conditions have exposed in timely manner a natural structural weakness in the subgrade which would have passed unnoticed had work been begun in the summer. At a depth of 1 to 2 feet there is stiff clay, and the surface soil is slightly plastic silty loam. Lenticular masses of loose "buckshot" ferruginous gravel exist at close intervals resting on the clay. The surface is generally flat and water therefore readily accumulates in the gravel and is held there in the natural basins of impervious clay. In the summer the surface loam is firm, and quite heavy loads are supported by the system of materials. When the gravel is full of water the loam behaves like a quicksand under even light loads. On this "crabhole" country formation work and compaction of surfacing materials were therefore impossible in winter. It has been necessary to loosen and mix the loam and gravel down to the surface of the clay, generally including some of the latter to a depth of about 2 feet, and to re-compact the mixed material to the desired subgrade contour, using a "sheepsfoot" roller. In this way a bad subgrade is converted into an exceptionally good one.

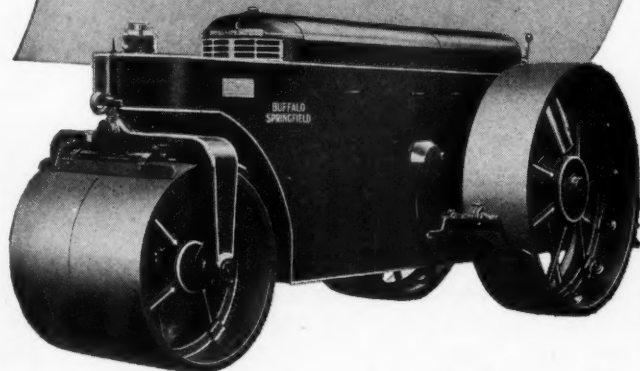
The tamping rollers available have been in constant use on subgrade compaction all the year in various special works where it was essential to secure as firm a foundation as possible and to get it as quickly as possible.

From the annual report of D. V. Darwin, chief engineer of the Victoria, Australia, County Roads Board.

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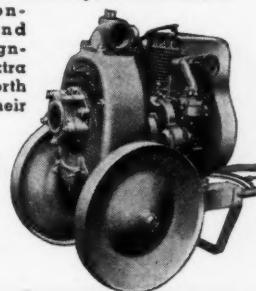


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All-Timber Overpass at Fort Lewis, Washington

Completion of an overpass across U. S. Highway 99, one mile northeast of the main entrance to Fort Lewis, Washington, to carry traffic over the heavily traveled road, has eliminated one of the worst traffic bottlenecks in the state, and has resulted in speeding up traffic on this main highway between Washington and the coastal states to the south.

In order to reach the training areas to the south, all equipment and personnel from the posts must move across Route 99. Because several accidents occurred at the junction of the military road and Route 99, during construction of the cantonment, Army authori-



Ft. Lewis overpass, 801 ft. long.

ties decided to preclude both accidents and traffic tie-ups by construction of the overpass and the job was assigned to the Work Projects Administration.

The structure is 801 feet long and has a clear roadway width of 24 ft. 9 ins. The span over the highway and the Northern Pacific Railway, which parallels Route 99 at this point, consists of a timber truss which has a clear span of 94 ft. 6 ins.

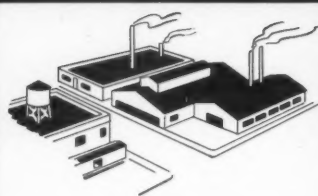
Floor beams consist of two 12" x 26" timbers. The top and bottom chords are made up of three pieces of 6" x 18" timbers, and are fastened together by means of ring connectors and safety bolts. The viaduct is of standard pile-trestle construction with a central bridge section designed without top lateral bracing to provide unlimited clearance for any type load.

Due to the heavy traffic on Route 99, it was impossible to erect the highway span in its proper place, and it was erected parallel to the highway and then swung into position. This was accomplished by placing, on the northeast corner of the structure, a pivot constructed of three plates, four inches square, fastened together with a two-inch pin, making a turntable. At the second panel point a tower was built of 12" x 12" timbers founded on skids of the same dimensions, under which were placed round oak rollers, to carry the skids over a track constructed over the pavement, in sections.

To handle traffic during the placing of the span, it was necessary to construct two detours, routed through two openings left in the pile approach on both sides of the highway. A traffic count taken during the time the span was being turned disclosed that an average of 1,900 vehicles passed each hour.

84-HD KETTLE

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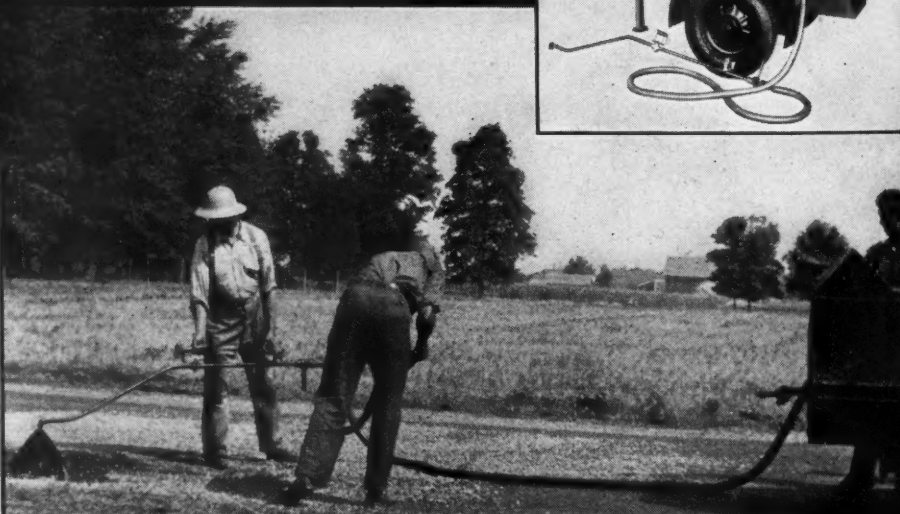
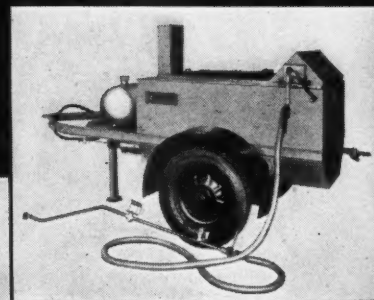


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The span was moved with the assistance of an 80 h. p. tractor equipped with a drum. The operation was started at 8 a.m. and by 4 o'clock in the afternoon the highway was cleared and open for traffic.

All labor on construction of the overpass was performed by employees of WPA. Piling was produced on the site by WPA crews. Work included clearing and grubbing three acres, and some 2,000 cubic yards of excavation. About 30,000 pounds of structural iron, 6,780 linear feet of piling, and 340 mbm of lumber were used in the construction of the overpass. Construction of the approaches to the overpass required 650 cubic yards of gravel ballast and 3,890 square yards of asphalt surfacing, plant mix.

Total Federal allotment for the project amounted to \$37,319 with the sponsor contributing \$1,850. However, due to the efficient supervision and workmanship of the WPA, only \$35,700 of the allotted amount was used.

Repairing War Damage to Sewers

An English engineer, in an article in "The Surveyor," gives some suggestions for repairing sewers that have been damaged by air raids, which we have abstracted with the idea that they may prove of interest to municipal engineers in this country, even though they fortunately may never be called upon to use them.

The authorities last year recognized the importance of having young and active men experienced in such work available for quickly repairing sewers, and have permitted town engineers to obtain deferment of active service for their assistants.

The damaged sewer should be inspected by a technical employee to determine just what should be done before the repair gang commences repairs. These should be permanent (this is the accepted policy in England regarding all war damages) except where there is urgent need for immediate filling of the crater, where there are more damaged sewers than the repair gang can handle promptly, or there is delay in obtaining materials.

Damage to the sewer may not be plainly evident. Bomb splinters have been found 20 ft. below the bottom of shallow craters, having damaged sewers and other conduits in their path; and sewers may be ruptured 10 to 20 ft. each side of a crater. The cracking of a sewer may not at once be apparent, and the sewers at and near a crater should be kept under observation for several weeks after the incident.

In making repairs, a firm foundation is the first essential. A concrete foundation slab or even piers may be necessary where good filling material is not available; but usually the debris from buildings damaged in the vicinity will furnish good material for this purpose. The time required for repairing can be shortened by using long lengths of pipe—cast iron, steel or other material, for this reduces the number of joints and the amount of foundation work necessary.

During repairs, the sewage flow can be handled by stopping the sewer at the nearest up-stream manhole and pumping the sewage to an outlet; possibly to the same sewer below the crater. Or the sewage can be carried across the crater in a trough or just a channel in the ground. Or, if the flow is not heavy, it may soak away into the ground around the crater.



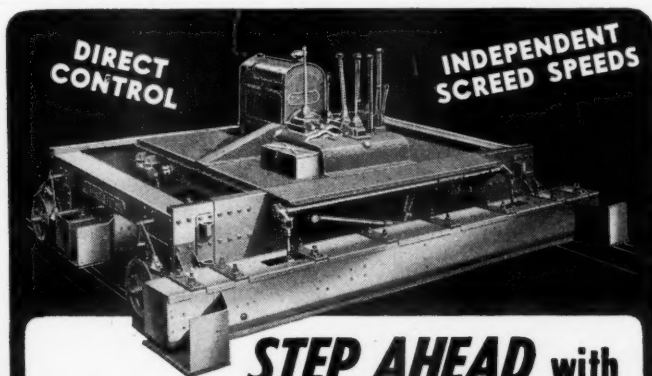
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As in normal times, a record should be kept of all details of the work done—kind and length of pipe used, exact location and depth, dates of beginning and ending, cost, foreman in charge, etc.

Rapidity of clearing up war damage, in whatever form, plays a great part in the support of morale.

Hill-Climbing Ability of Motor Trucks

The problem of eliminating the traffic congestion that results from slow-moving vehicles on grades has been investigated in an exhaustive study of motor truck performance made by the Public Roads Administration in cooperation with the Automobile Manufacturers' Association, the Maryland Motor Truck Association, the National Bureau of Standards, and the Quartermaster Corps of the Army.

The study was divided into three distinct but closely related parts: A study of the performance of new motor trucks in the best of condition; a study of the performance of used motor trucks in various stages of wear and having traveled various mileages; and a study of the hill-climbing ability and the driver behavior of a large number of motor trucks and passenger cars as they operate in every day traffic.

Actual grade tests, the most important part of the new truck study, were made on 30 new truck chassis. The results of these tests showed that for motor trucks even to approach reasonable speeds on grades: Grades must be reduced to 3 percent or less; or engine power must be more than doubled; or gross vehicle weights must be reduced excessively; or some combination of the three must be used that will still be costly to all interests involved and impossible of immediate application.

Deceleration tests were made on each new truck to determine the coefficients of tractive resistance. The most significant finding was that not only the total tractive resistance but also the unit resistance in pounds per 1,000 pounds varied appreciably with weight. The efficiency of the transmission of power was also determined for each new vehicle from the results of the actual grade tests. The evaluation of these two factors makes it possible to compute the performance of a motor truck from its specified characteristics with a fair degree of accuracy.

The results of the actual grade tests were also used to appraise cheaper and shorter methods for determining the grade ability of motor trucks. The acceleration method proved to be the most satisfactory and was adopted for use on the used truck study.

Tests on 17 used trucks of the same make and model as the new trucks tested showed that not over a 10 percent decrease in performance should be expected from wear and mileage. The results also proved definitely that trucks can be maintained so that their performance does not decrease with reasonable use.

The study of motor trucks in actual service under ordinary driving produced results that showed a 30 percent variation between the possible performance and the actual performance of vehicles of the same weight and capacity. Since not over 10 percent of this variation should be due to lack of maintenance, there remains a 20 percent variation that must be charged to improper operation of the vehicle. The shifting of gears at improper speeds was the principal reason for the variation in performance.

Abstract of a report in the May issue of "Public Roads."



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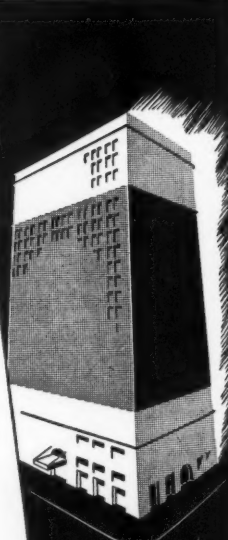
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General view of Findlay, Ohio, plant. Main building at right; sludge beds and digester at left.

Sludge as Fertilizer in Oshkosh

Oshkosh, Wis., since 1937 has sold its sewage sludge for fertilizer at 20¢ a bushel or \$3.50 a cubic yard if ground, and 10¢ a bushel or \$1.75 a cubic yard as taken from the sludge bed. Freezing and thawing on the bed in winter makes it mealy so that it does not have to be ground, but in summer it is ground in a hammer mill operated by gas from the digestion tanks. Receipts from the sale total over \$800 a year.^{G3*}

Reconstructing Sewer for Low Headroom

A 4' 6" brick sewer, crossing at a long angle under several railroad tracks which were only a few inches above the sewer arch, was so deteriorated by the jarring that it became necessary to do something. The five tracks were in a main line terminal in constant use and it was impracticable to build in open cut in the usual way or to tunnel. The longest time any part of the right of way could be out of use was 10 hrs. following Saturday midnight—not long enough to permit opening up even a short stretch, removing the old sewer and rebuilding a new. The plan successfully carried through was as follows: Thirty-three pre-cast reinforced concrete units were made, each being practically a bridge 4' long, complete with abutments 3' 6" deep and 3' wide connected by a 6' span 14" deep containing four 40 lb. steel beams. The under side of the unit was made of such shape as to serve as the top of the sewer down to the spring line. Each unit was therefore 4' x 12' by 3' 6" deep, and weighed 8 tons.

An average of four units were placed each week end. Track was removed, 16' of trench 14' wide was dug about 6 ft. deep, using compressor tools, and foundations for the abutments laid, using quick-setting cement reinforced with a double grill of old rails. Then the sewer arch was removed and the pre-cast units swung into place by means of a railroad crane. Then the ballast was replaced and track laid. Only once was the track not ready for use at 10 a. m. Sunday.

After the completion of this work, the lower half of the sewer was rebuilt from the inside, the new walls connecting with the arch formed by the underside of the units described above. The total cost was £2,733 (about \$100 a lineal foot of sewer), a large part of which was expenses incurred by the railroad in connection with the work.^{D17}

Record Forms At Buffalo Works

Development of office forms for the Buffalo, N. Y., treatment works was based on 7 major premises: All forms are on standard 8½ x 11 in. paper, punched for filing; with a standard heading on all sheets; printed by mimeograph; with columnar spacing based on number of digits to be entered. In addition to daily logs, there are monthly summary sheets containing totals, max., min. and daily averages for current and previous month and same month

*See Bibliography in the May issue.

The Sewerage Digest

Abstracts of the main features of all important articles dealing with sewerage and sewage treatment that appeared in the previous month's periodicals.

of previous years. Average data on concentrations and analyses are calculated on a weighted basis from quantitative data. There are 4 categories of forms: Daily Logs, Laboratory Data, Plant Reports, and Miscellaneous.

Laboratory data recorded include weather and flow; ppm; bacterial results; sludge digestion; sludge dewatering; grit, ash and gas analysis; thousand pounds of solids; B.O.D. and chlorine demand; bacterial results; digester operation, and solids disposal.^{C39}

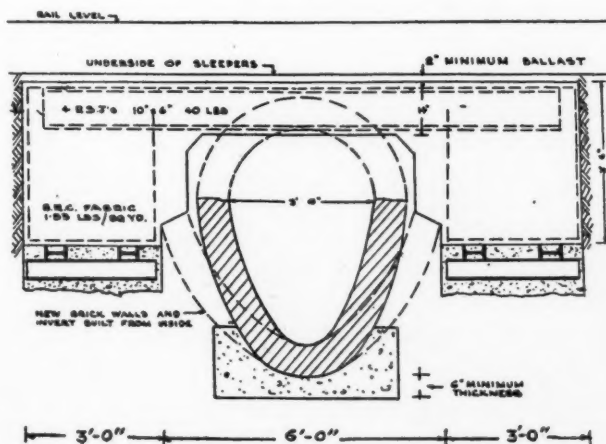
Elutriating Hartford Sludge

Hartford, Conn., treats 25 mgd of sewage in a plant with 40 mgd capacity, using digestion, elutriation and vacuum filtration. After three years' experience with elutriation it finds that 2.5 lb. of ferric chloride per 100 lb. of solid matter is sufficient with elutriated sludge, while 5.6 lb. is necessary without elutriation. Plant for elutriation increased the first cost by \$44,400, but decreased yearly cost (including 8% for interest and depreciation) by \$1,048, which will increase to \$2,800 when the plant is treating 40 mgd. Elutriation also shortened digestion time, permitting using smaller digestion tanks at a saving in construction cost of \$59,800.

Plenty of washing water is necessary. Comparing results with water ratios of 5:1 and 1.9:1, the filter rates were 9.04 lb. per sq. ft. per hr. and 6.49, respectively; although the ferric chloride rates were 1.51 and 3.07% of dry solids, respectively. Best results are obtained by keeping pH of filtrate between 6.0 and 6.3.^{C43}

Determining D. O. In Activated Sludge

No satisfactory method has been proposed or developed for determining the dissolved oxygen in mixed aeration liquors in connection with activated sludge plant control. This is difficult because of the presence of zoogeal sludge



Typical cross section of a construction unit in place and the old and reconstructed sewer.

floc, the biochemical oxidizing capacity and oxygen demand of such floc, and the very frequent presence of nitrites in the mixed liquor. The author proposes use of an inhibiting reagent composed of sulfamic acid, acetic acid and copper sulfate; which is about twice as effective as copper sulfate used alone, though it contains only one-half the original concentration of this salt and consequently does not interfere with the end point in the iodine titration. When activated sludge is brought into contact with this reagent, oxygen absorption is stopped, nitrites are destroyed and the sludge is coagulated. The dissolved oxygen may then be determined upon the separated supernatant by the application of the short Winkler procedure employing sodium azide in the alkaline iodide solution. This method is simple and dependable.^{C45}

Cross Connections In Sewage Plants

There should be no direct connection between a potable supply and sewage. If water is taken from a potable supply it should discharge by gravity freely into a tank, from which it is taken for use. If the supply must be used under pressure (as for washing tanks) a temporary hose or pipe connection can be used which will stay connected only so long as the connector is held in place by the operator's hands.^{C40}

The purpose of each pipe in a plant should be designed by painting it. In one plant, sewage pipes are black, sludge pipe brown, water blue, air white, chemical yellow. In every case of use of potable water it should be assumed that the pressure in the water pipe may sometimes be negative. This might occur when the end of a hose used for washing a tank was left submerged in sewage. Dangerous cross-connections sometimes found are those for flushing venturi meters on sewage lines; for priming sewage pumps and for water seals; for flushing sludge lines; for vacuum ejectors; digester seals; hydraulic valve cylinders. The only certain precaution is to have

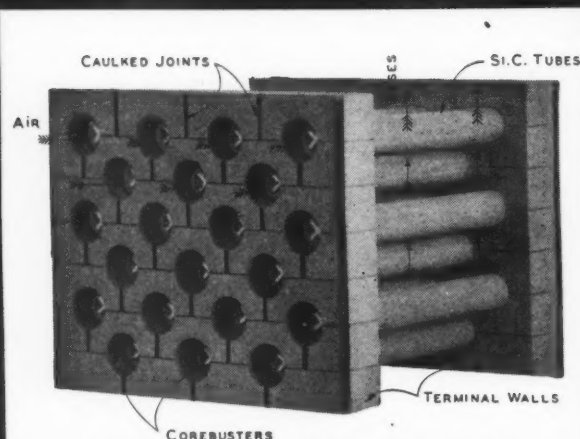
the potable water fall freely into an open tank and use it from that, pumping it if necessary.^{C41}

Plant for Dissolved Oxygen

Trickling filters at Dayton, O., were placed at sufficient elevation above the river to give 18 ft. fall from weirs of final settling tanks to minimum low water stage, which fall was utilized to increase the D. O. at times of low river flow, when this is most necessary. The oxidizing devices, and the typical D. O. average at the lower end of each one as follows: In the tank, 4.0 ppm. Effluent flowed over V-notch weirs, falling 4½ in. onto a concrete ledge, having a 45° slope into a trough, then through 50 ft. of open channel with three 5" drops; this increased the D. O. to 4.4. Then 250 ft. of closed conduit, a 3 ft. 8 in. fall into a 6 ft. sewer 410 ft. long; here D. O. was 5.9. Then an open paved ditch 6 ft. wide and 6" deep, 0.4% grade, 440 ft. long; here the D. O. was 6.1. Then 300 ft. of ditch on a 1.38% grade, containing large boulders embedded in the concrete bottom, at the end of which the D. O. was 6.5. At lowest water there is an additional 2 ft. drop. A number of tests over a three-month period gave D. O. of effluent varying from 6.2 to 6.9 ppm.^{C42}

Selling Sludge At Spartanburg, S. C.

About 5½ mgd of sewage is treated at Spartanburg and the sludge digested in two plants. For some years the sludge has been sold to a local fertilizer concern at \$1 a ton base price for the humus and an additional \$1 per unit of nitrogen. The sludge had to be dried to 10% moisture content, which was found to be difficult if spread on the ground, and a flat concrete slab 100 x 250 ft. divided into 50 ft. bays was built, with a drainage trough in the center of each bay, on which sludge from the sand sludge beds was dried. This was quite successful, lowering moisture to 7% in some cases.^{H28}



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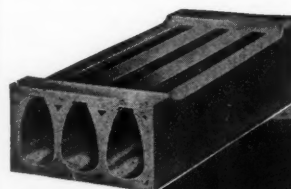
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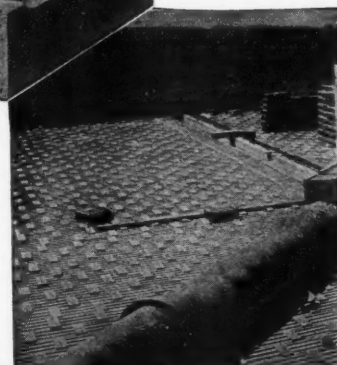
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c. Indicates construction article; n, note or short article; p, paper before a society (complete or abstract); t, technical article.

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April 10
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May
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 27. Sewage Treatment Plants in U. S. Pp. 247-251.
 28. The Oil Problem at Pontiac. By Floyd L. Vermette. P. 252.
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May
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May
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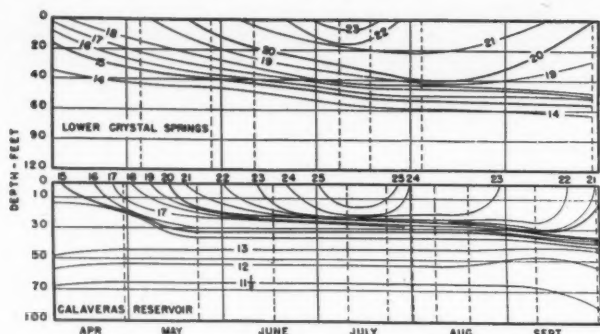
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Isotherms of Vertical Sections of Calaveras and Lower Crystal Springs Reservoirs—April-September 1941.

Financing Main Extensions

Of California's 18 largest cities, 3 finance main extensions from water revenues without charge to the property owners; 7 finance from revenues but require a deposit to guarantee sufficient revenue from the new main to justify the investment; and 8 charge all or the greater part of the cost to the property benefited. In each city, the present policy has been in effect for many years and appears to be satisfactory to both utility and customers.

If extensions are financed from revenue, present consumers pay higher rates in order to finance a capital investment to serve future consumers, but the cost of this is not large enough to affect the base rate materially. A large extension program is often financed by a bond issue retired from future revenue. A deposit should be required to prevent property owners from asking for extensions not actually needed. The direct assessment method was employed by the very rapidly growing cities.^{A61}

With recent dispersion of population, cost per capita of distribution systems has increased and charges or guarantees for extensions should allow for this. Each new customer is an additional load on the plant, and if an operator is to be on safe financial ground he should determine the amount of capital investment for each present revenue dollar and not let investment for extensions exceed this; keeping in mind that maintenance costs of the new extensions will probably exceed those for old because they extend further from operating headquarters.^{A62*}

Temperature And Coagulation

At Durham, N. C., filters are washed when the effluent shows more than 0.2 ppm turbidity, or when the loss of head reaches 8 ft., whichever occurs first. In cold weather the floc is finer, and turbid effluent always necessitates washing while the head is still low. In summer sometimes one condition, sometimes the other, necessitates washing. It was suggested that longer mixing time in cold weather would produce larger floc, but the capacity of the mixers does not permit this. In winter the best effluent occurs a few hours after being washed; in summer, maximum efficiency is reached the second day.^{X12}

Water for Bottling Plants

A bottled beverage is 8 or 9% water, which must have a pleasant taste and odor, a pH of 2.7 to 3.5, be permanently clear. To secure this, bottlers generally have to treat the municipal supply. Generally the organic matter is destroyed by superchlorination, and the excess chlorine and residual organic matter are then removed by activated carbon filters, all suspended matter having first been filtered out.

Beverages should be more or less acid, hence alkalinity should not exceed 50 ppm to 100 ppm. For softening, lime treatment is the usual treatment; zeolites may be used for water high in sodium bicarbonate. Permanent clarity is

*See Bibliography in the May issue.

The Waterworks Digest

Abstracts of the main features of all important articles dealing with waterworks and water purification that appeared in the previous month's periodicals.

obtained by coagulation, superchlorination, clarification, sand filtration and activated carbon filtration.^{X13}

Water for Textile Industries

Bleaching requires about 3,000 to 4,000 gal. of water per 100 lb. of cotton goods bleached, and dyeing 400 to 800 gal. For fine textile operations the water should have turbidity, color, hardness, iron and manganese as near zero as possible. To secure this the usual procedure is coagulation, sedimentation, filtration and softening; also special iron and manganese removal in some cases. Iron more than 0.2 ppm affects the shade of dye. Turbidity, hardness and color affect shades and cause spots and streaks. Sediment causes spots.^{X14}

Biological Changes in Reservoirs

Stratification of bodies of water is governed principally by depth of water, air temperature, radiant energy and wind velocity. Data on these points have been collected at two of San Francisco's reservoirs; Calaveras, 31.5 billion gallons capacity, 1420 acres area, and Lower Crystal Springs, 11.3 billion gallons, 620 acres. The reservoirs stratified at depths of 20 to 60 ft., but each reservoir has its own stratification characteristics, practically the same each year. In that locality the overturn is gradual, about 2 months elapsing between the time the thermocline begins dropping and that when the reservoir is in complete circulation. There is a marked change in pH and dissolved oxygen as well as temperature in the transition zone. Both reservoirs absorbed the same amount of heat per unit area for an equal depth (120 ft.) between the times of minimum and maximum water temperature, although their heat distribution with depths was very different. In such reservoirs aeration is advisable if water is to be drawn from the transition zone or below during the stagnation period. It is desirable to have facilities for drawing water from several levels.^{A80}

Locating and Drilling Wells

About 36% of all water-borne outbreaks in the United States between 1920 and 1936 were caused by pollution of underground sources of supply. Prevention of such pollution may logically be separated into three major phases: 1—selection of site with respect to environment; 2—sub-surface construction; 3—surface construction. Perhaps the best information on underground pollution is U. S. Public Health Service, Hygienic Laboratory Bulletin No. 147.^{A71}

Having selected the location and type of well, the method of construction it is important. This is almost always by contract. Bidding should be limited to well drilling contractors who specialize in the construction of the type selected, using the method of prequalification legal in the State. In the "guaranteed well" contract a lump sum is bid for a completed well delivering a certain minimum quantity of water, generally with a bonus for delivery in excess of this. In this the client is assured of the desired

amount of water at a known cost, but this cost is necessarily high, and the client and driller may not be able to agree on the site.

In a "unit price" contract the bid is per foot of well complete, or per foot for drilling plus material. The cost is usually lower than in the guaranteed, the client has more control of the operation, but he may not get the desired supply.

The least certainty of supply is furnished by paying the driller a fixed rate per day plus cost of materials. Only experienced drillers with adequate equipment should be allowed to bid. Engineers find this the most satisfactory contract in the long run.^{A72}

The development of underground water is a highly specialized art, requiring that both engineers and contractors be qualified by practical experience. It is not safe for a client to contract without the advice of a qualified engineer. State licensing of well contractors is desirable, to give protection to the owners.^{A73}

Cleaning Well Screens

At La Crosse, Wis., wells 108 to 135 ft. deep had a draw-down or vacuum of 11" to 14" at first, but 22" to 24" five years later. Surging reduced it only to 16"-17". Eight years later the screens were found to be practically destroyed, CO₂ gas having dissolved the zinc from the brass; and they were replaced with "Everdur" screens. Incrustation formed on these also, and was removed by acid, increasing the yield per well from an average of 0.3 mgd to an average of 0.5 mgd, at a cost of about \$200 per well. Muriatic acid in a 25% solution, an inhibitor to prevent the acid from destroying the casing and screens and a stabilizer to keep the dissolved incrustation in solution was pumped into the well under pressure, Dow metal having previously been placed in it so that its reaction with the acid raised the temperature to 175°. After about an hour a 15%

solution was pumped in, forcing the stronger solution out into the sand. After a half hour, clear water was pumped in to force all the acid into the sand. Then the acid water and loose material were pumped out until no acid remained.^{A76}

At Eau Claire, Wis., capacity of four wells dropped from 7,090 gpm to 3,350 gpm in four years. Bacterial growth in the pipe lines suggested this might be the cause of the well decrease; and as chlorine had remedied the pipe trouble it was tried in the wells, a chlorine solution being forced back into the well. The yield of the well No. 1 before this treatment was 395 gpm, after treatment was 1,740 gpm. (Its original capacity had been 1,850.) Well No. 4 was increased from 515 gpm to 1,400. No. 1 two years later had fallen to 1,540 but chlorination increased it to 1,780. In the first chlorine treatment of No. 1, 30 lb. of chlorine was used and considerable algae came out; 7 days later another 30 lb. of chlorine was applied, well pumped and backwashed; 3 days later 60 lb. of chlorine was applied and well pumped and backwashed for 2 days, then put into service.^{A77}

Water Softening For Kansas City

Kansas City, Mo., is completing a plant for softening 150 mgd to supplement a 100 mgd filter plant built in 1928. The cost—about \$900,000—is being met out of Water Dept. revenue, and the increased operating expense of \$150,000 to \$200,000 a year will be met by a 30% reduction in operating personnel (which a new administration found to be unnecessarily large). The hardness will be reduced from 215 to 90 ppm, saving consumers an estimated \$350,000 a year in soap. Moreover, the improved conditioning will permit operating the present filters at 3 gpm per sq. ft. instead of 2 gpm as at present.

At present about 400 lb. per m.g. of lime and alum are used as coagulants; 1600 to 1800 lbs. of lime, soda ash and



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alum will be used for softening. Breakpoint chlorination will probably be used. Flocculator clarifier equipment was adopted rather than the sludge blanket type, partly because abundant basin capacity was already at hand.^{A78}

Developing Deep Wells

Dynamiting deep well water-bearing formations in most cases increases capacity and raises pumping water levels. Dynamiting a well in sandstone releases a tremendous explosive pressure which frees the water from suspension in the interstices of the sandstone and also causes large breaks and cavities in the stratum, often increasing the specific capacity 50% or more.^{A74}

Capacity of wells in the red sandstone of northern New Jersey has been increased from 25% to 180% by agitation. Apparently the surface of the bore hole becomes sealed, during the drilling, with clay formed by drilling through interspersed strata of shale. In one 12" well the wall was scrubbed with a steel brush having $\frac{1}{4}$ " bristles, $12\frac{1}{2}$ " diameter, before using the surge plunger.^{A75}

Dispersion of Copper Sulfate

Copper sulfate is applied by San Francisco by spraying a solution of known strength over the water surface behind a motor boat. The boat exerts a mixing effect for about 300 ft. on each side. An hour after treatment every sample taken showed some copper, the maximum concentration being 0.18 ppm. Some copper reached the bottom within three hours. A week after treatment the concentration was nearly constant throughout the reservoir. The copper precipitated out as a hydroxide did not tend to settle until five weeks after treatment. After six weeks copper concentration of the surface water was about 0.03 ppm, and continued to decrease for 48 days, when algae growths appeared and the treatment was repeated.^{A81}

Materials Required For Public Water Supplies

There are about 12,800 water works plants in the United States, of which 9,300 are municipally owned and operated. About 82,000,000 people are supplied, of which over 19 million are in cities of less than 10,000 population.

A study of available data indicates that for each 1,000 persons served, about 300 tons of metal are required for construction of the works. Nearly 5 tons a year are required for maintenance and repair only; the total for all plants being about 348,000 tons of cast iron, 42,600 tons of steel, 9,000 tons of copper, 5,735 tons of lead, 2,100 tons of zinc, tin, aluminum, etc., 210 tons of nickel and 245 tons of rubber. Water meters require a little over 0.5% of the metal used in a distribution system, but reduce the total needed by at least 25% by lowering the quantity of water to be delivered.^{A82}

Sand in Well Water

Houston, Tex., in 1939 installed Brassert mechanical strainers to remove sand from well water. (See "Digest" for March, 1941, and the 1941 edition of The Manual of Water Works Equipment.) This is essentially a cone-shaped drum rotating on a vertical shaft, in which are 200-mesh screen openings, through which the water passes from the outside, leaving the sand which is flushed out by intermittent reverse flow of clean water. At first the screens clogged rapidly, chiefly because the sand was coated with a gelatinous organism in the wells; but chlorination removed this, lessening the clogging; and back-washing from the high service mains completed the remedy; which back-washing is started automatically by increase of differential of the pressures on the feed and discharge sides of the screen.^{G19}

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- May 6
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- May 20
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- April
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- May
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- May
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M *Water and Sewage*

- April
9. p. Modern Trends in Pumping Station Equipment. By Norman G. McDonald. Pp. 35-39, 67.
 10. p. Influence of Plant Design and Construction on Water Filtration Problems. By Henry F. Wagner. Pp. 40-41, 63.
 11. p. Wartime Supply Problems as They Affect Public Utilities. By M. J. McHenry. Pp. 42-43, 114.
 12. p. Wartime Control Over Public Utilities. By A. E. K. Bunnell. Pp. 44, 110.
 13. p. The Future of Water Chlorination. By Harry A. Faber. Pp. 76, 79, 80, 113.

P *Public Works*

- May
18. The New Water Supply System of Muskegon Heights, Mich. By George F. Liddle. Pp. 16-18.
 19. Filter Maintenance at the Griffin, Ga., Water Works. By Lewis R. Simonton. Pp. 28, 41.
 20. n. Truck Distribution of Water. P. 37.
 21. Poisonous Chemicals and Pathogenic Bacteria in Water Supplies. P. 38.

V *Journal, Maine Water Utilities Assn.*

- May
4. Laws Governing Water Utilities. By David E. Moulton. Pp. 52-69.

5. c. Laying a Submarine Water Main Across a Tidal Inlet. By L. G. Smith. Pp. 72-76.

X *Journal, North Carolina Water & Sewage Works Assn.*

- April
11. Water and Sewage Plants at High Point. By A. J. Setzer. Pp. 32-40.
 12. Experiences With Cold Water Coagulation at Durham. By J. R. Malone. Pp. 41-50.
 13. Industrial Water Requirements. By A. S. Behrman. Pp. 51-61.
 14. Industrial Water Requirements of Textile Industry. By John L. Brown, Jr. Pp. 61-63.
 15. Water Requirements of the Pulp and Paper Industry. By Henry Seaman. Pp. 63-64.
 16. Requirements of Water for Bottling Carbonated Beverages. By John M. Sharf. Pp. 65-71.
 17. Maintenance of Elevated Tanks. By H. F. Stearns. Pp. 123-128.
 18. Conservation of Steel With Cathodic Protection. By Edward B. Shiddell. Pp. 128-133.

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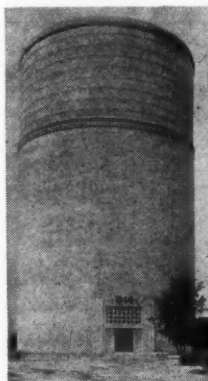
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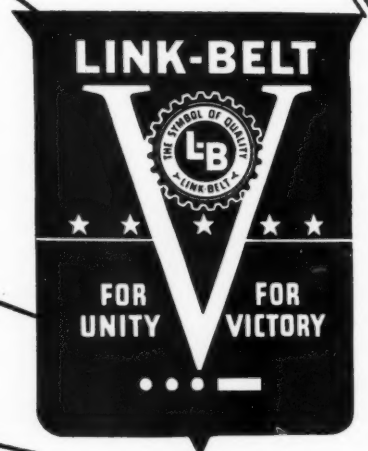
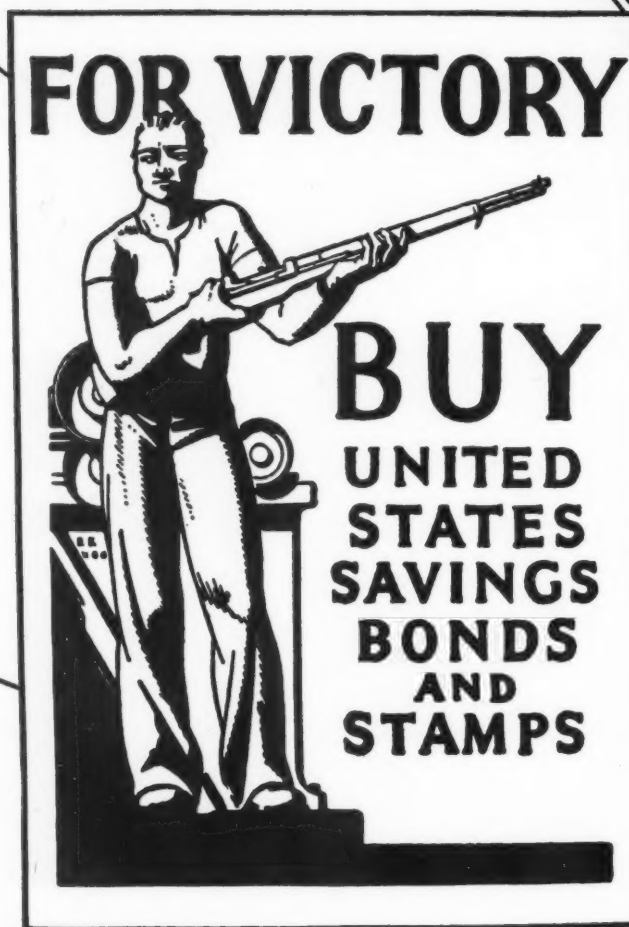
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206 Cottage St., Bridgeport, Conn.

Keeping Up With New Equipment



Graver Chemical Proportioner.

Chemical Proportioner

Graver Tank & Mfg. Co., Inc.
4809-15 Tod Ave.
East Chicago, Ind.

Graver Chemical Proportioner—A new device providing accurate control of the feed of chemicals into the water treating plant in proportion to the volume of water.

Equipment insures uniform treatment at all times regardless of volume of water entering treating plant. Permits instant increase or reduction of chemical charge over a wide range should water require change of treatment.

Proportioner is readily adapted to any make of solution type chemical feeder where swing pipe or skimmer can be installed in chemical feeder.

Write for bulletin 310 describing this equipment.

Manual On Repair of War-Damaged Water Lines

Johns-Manville Corp.
22 East 40th St.
New York, N. Y.

Said to be the first publication devoted to a detailed treatment of the restoration of war-damaged water mains, a new 92-page engineering manual on the repair of water lines damaged as a result of enemy action has just been published by Johns-Manville. It is designed to provide the detailed information needed by officials responsible for the maintenance of service in cities, as well as at military flying fields, bases and other critical areas vulnerable to bombing attacks.

Written especially for the users of Transite asbestos-cement pipe, the manual is divided into five parts: The first showing actual photographs of bomb damage; the second, typical damage suffered by pipe lines; the third, temporary and permanent repairs; the fourth, installation methods; and the fifth, a

group of appendices treating of all the repair parts and tables referred to in the text. Typical experiences with asbestos-cement pipe in bombed British cities are also cited.

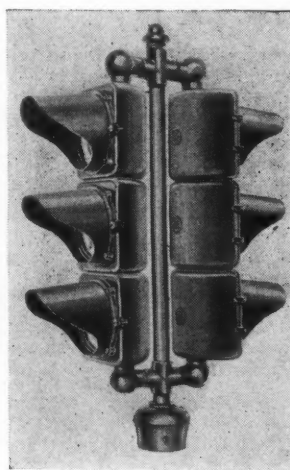
The manual is offered without charge to waterworks operators, consulting engineers, army and navy engineers, plant engineers, and others who may need it. Copies of the book, DS Series 350, may be secured from Johns-Manville, 22 East 40th Street, New York, N. Y.

"Fifty Years of Chemical Progress"

Mathieson Alkali Works
60 E. 42nd St.
New York, N. Y.

Commemorating its fiftieth anniversary, Mathieson has published a 48-page booklet which traces the growth of the Mathieson organization and describes the company's major developments. It includes the introduction of liquid chlorine and synthetic ammonia, the preparation of new chlorine carriers, bleaching agents, and detergents, and the production of alkalis of an exceptionally high degree of purity. Numerous illustrations show the scope of the company's present operations.

Copies of the booklet can be obtained upon request, as long as the limited supply lasts.



General Electric Traffic Signal.

New Traffic Signal

General Electric Co.
Schenectady, N. Y.

This new all-steel traffic signal combines a high-visibility lens with an exclusive phantom-proof feature. The reflector is made of silvered glass and is specially designed to meet I. T. E. specifications.

The "Internal Sun Phantom" is that characteristic of a signal which makes it appear lighted when in the path of

the sun's rays. The phantom-proof nature of the signal eliminates this dangerous characteristic.

The adjustable signal consists of single sections which are joined together by means of clamping plates and short bolts to form an attractive and highly efficient signal assembly. Each section has a strong weatherproof sheet-steel housing in which the optical unit is mounted.

The steel housing is strong so as to withstand the shocks of traffic accidents, and the light weight facilitates suspension mounting. These qualities mean low maintenance and replacement costs and save the time and expense of frequent repairs.

Two orienting bosses are provided so that the signals are perfectly aligned. The bosses can be removed so that the sections may be rotated with respect to each other. Write the company for more complete information.

Offers Design Assistance On Wood Water Towers

Timber Engineering Co.
Washington, D. C.

This company says inquiries are being received for aid in designing wood towers for water tanks.

The company has several designs, listed below, on hand and is distributing them free upon request:

No.	Type	Height	Size in gals.
250	Water Tank	30'-0"	2,000
250A	Water Tank	30'-0"	5,000
12	Water Tank A.R.E.A.	30'-0"	50,000
	Water Tank A.R.E.A.	30'-0"	100,000
186	Water Tank	60'-0"	50,000

Timber Engineering Company also has in preparation a design for a 100-foot tower to carry a 100,000-gallon wood tank, which will be ready soon and will be given free upon request. The company offers co-operation in designing tank towers, and will send complete design data and recommendations to assist in design work, and will examine designs submitted and give advice on the adequate use of the timber connector system of construction.

Wallace & Tiernan Uses New Plan In Aiding Navy Relief

A novel plan of painless giving for industrial employees has been developed in the New Jersey Navy Relief campaign, it was revealed this week when the workers and the management of Wallace & Tiernan Co., Inc., presented the committee with a check for \$6,500.

Devised as a means to permit every employee to contribute without burdening the family budget, this plan is thought to be original with Wallace & Tiernan Industries. During the week, each of the 1500 employees gave one hour of overtime work. The value of this work was calculated in terms of finished products and a sum representing an additional contribution of the Company was added. The program served a two-fold purpose because the finished products are additional materials all vitally essential to the war effort.



Martin Tiernan hands check for \$6,500 representing Wallace & Tiernan employees contribution for Navy relief to Capt. Reynolds Hayden.

Martin Tiernan, President of Wallace & Tiernan presented the check to Captain Reynolds Hayden, Medical Officer of the Third Naval District at a ceremony attended by some 2000 spectators. Captain Hayden, who was in command of the base hospital at Pearl Harbor on Dec. 7 told of the great help which had been extended by the Navy Relief Society to the families of Naval personnel casualties after the savage Japanese attack.

Clarence Dillon, Chairman of the National Citizen's Committee of the Naval Relief Society presented a Certificate of Honor awarded by Frank Knox, Secretary of the Navy. The certificate to which was appended a scroll containing the names of all W & T employees, was accepted by Charles F. Wallace, Vice-President on behalf of the Management and by Miss Bertha Lindsay and John Walker on behalf of the employees.

The Empire Victory Meter
Pittsburgh Equitable Meter Co.
400 N. Lexington Ave.
Pittsburgh, Pa.

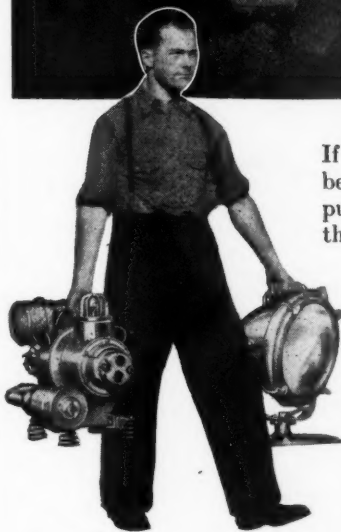
The Empire Victory Water Meter is designed with a cast iron outer case and a molded glass register box to conserve vitally needed brass for the war effort. The manufacturer states that about 70% of the bronze normally used in a domestic size meter has been eliminated, without sacrificing any of the quality construction details that have for 72 years been associated with the Empire name.

It is stated that the cast iron outer casing of the Empire Victory Meter is especially treated, coated and lined to prevent the formation of rust. Machined surfaces are chemically treated to inhibit corrosion. The casting surfaces are protected with a coating of "Resistin," which is described as a special synthetic resin enamel finish, permanently bonded to the metal. Lead alloy liners are provided at all points of contact between the measuring chamber and the outer shell.

Of especial interest is the molded glass register box. This is described as a single-piece, strong, molded glass unit which fits snugly over the register and is retained against a fibre gasket by two screws. The manufacturer states that the

READY FOR ANYTHING

Homelite Portable Pumps and Generators are veterans of many emergencies—floods, hurricanes, fires, serious power failures and several others. Wherever emergency floodlighting or instant pumping or quick repairs have been necessary, Homelites have been right on the job. Now these readily portable, self-operating units are ready for a greater emergency — WAR. Thousands of water works and public works departments have them on hand ready for any blitz.



A Homelite Generator (above) and a Homelite Pump are easily carried by one man—transportation difficulties are eliminated. Action is insured.

If bombs blow up water mains, Homelite Pumps can be put right on the job. They'll have the craters pumped out in no time so that repair crews can do their work with a minimum of delay. And if it comes at night, Homelite Generators will give men the floodlighting they need for speed. Also for fighting night fires caused by bombings; or for power standby at telephone or signal stations; illuminating hospitals, Red Cross stations, and defense centers, Homelite Generators will be at their posts ready to do their duty.

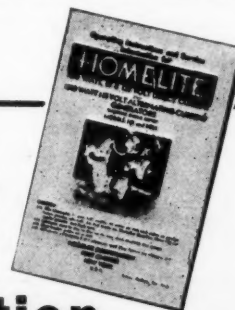
Homelite Pumps and Generators can take it. Those that have them know they are built to stand up without failure under the most severe operating conditions.

KEEP 'EM FIT FOR THE JOB

A few simple precautions such as keeping spark plugs clean, carbon out of the cylinders, the right mixture of oil in the gasoline, etc. will keep your Homelites in the pink of condition. Send for our service bulletins that show how to get the most out of your units. Specify model and serial numbers of the Homelites you now have.

Homelite Corporation

2406 RIVERDALE AVE., PORT CHESTER, N. Y.





Empire Victory Meter.

glass used is thick and strong and that it will withstand considerable abuse. The design permits this glass unit to serve both as a register box and as a lid.

The Victory Meter utilizes the same oscillating piston principle of measurement that has proven so successful in all Empire meters. The measuring chamber is of the snap joint type, within which operates a balanced piston having a centrally located web. The design requires the use of only three interior bronze castings. A four-wheel, oil enclosed gear train is provided—the top half of the measuring chamber acting as the gear train bottom plate. The design is described as eliminating all need for interior screws, and makes possible

the assembly of all working parts as a complete unit before installation in the meter case. A new bulletin describing the Empire Victory Meter may be obtained by writing to the company.

Trail-Dump Catalog

Koehring Co.
3026 W. Concordia Ave.
Milwaukee, Wis.

New folder describes and illustrates a new model 120 Koehring Trail-Dump and presents the machine as a complete unit with individual assembly illustrations, clearly showing the operating functions and the many special features of that new high-speed dirt hauling piece of equipment. It is mounted on rubber tires and the manufacturer says it has proven to be exceptionally economical in maintenance and enables low cost per yard performance, therefore it is especially suited for speeding up war production projects. Copies of this folder are available upon request.

PERSONALS

Major William H. Weir, Sanitary Corps, former Associate State Sanitary Engineer of Georgia, has been ordered to active duty and assigned to Headquarters, Sixth Corps Area, Chicago, Ill., as assistant to the Corps Area Surgeon.

Capt. David B. Lee, Sanitary Corps, State Sanitary Engineer of Florida, has been ordered to active duty and has been stationed temporarily at Stark General Hospital, Charleston, S. C.

Albert A. Ross of Lexington, Mass., President of the Anthony Ross & Son, Inc., Contractors, and former Selectman of the Town of Lexington, has been commissioned a Captain in the U. S. Army Corps of Engineers. Captain Ross was a Marine in World War No. 1.

Pittsburgh Plate Glass Co. has appointed R. W. Miller as manager of the technical service department of the Columbia Chemical Division. He joined the company in 1930 after receiving a B.S. degree in chemistry at Penn State College and has been active in promoting the principles of soil stabilization for highway and airport runway construction.

Conventions and Association Meetings

American Water Works Assn. annual meeting at Stevens Hotel, Chicago, Ill., June 21-25. Harry E. Jordan, Secty.

The Pennsylvania Sewage Works Association's 1942 Conference will be held at the Penn-Harris Hotel, Harrisburg, Pa., August 25th and 26th.

Pennsylvania Water Works Operators Association—Annual meeting will be held at Penn-Harris Hotel, Harrisburg, August 27th.

New England Water Works Assn., annual meeting will be held at Poland Springs, Me., Sept. 15-17.

Federation of Sewage Works Associations Annual Convention will be held October 22-24 in Hotel Statler, Cleveland, Ohio.

52nd Street Bridge at Chicago



Designed by:
Chas. DeLeuw & Co.
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Workman applying the Mineral Surface Asphalt Plank over the timber bridge deck that has been mopped with hot asphalt; while in the foreground the men are nailing the Mineral Surface Plank into position.

RECENTLY RESURFACED with SERVICISED MINERAL SURFACE ASPHALT PLANK

Servicised Asphalt Plank can be applied under any climatic conditions over timber, steel or concrete decks. This product is the best light-weight, non-skid bridge flooring for this type of installation.

Mineral Surface Plank absorbs shocks and vibrations, and is resilient at all temperatures. The material remains smooth without appearance of wearing or cracking and is, therefore, especially prepared to meet the heavy traffic conditions in large metropolitan centers.

The Michigan Avenue Bridge in Chicago was completely resurfaced in 1939 with Servicised Mineral Surface Asphalt Plank and is lasting better than ever!

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Upon request, our engineering department will gladly assist you on any flooring problems.



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6051 West 65th Street,

Chicago, Ill.

Readers' Service Department

These booklets are FREE but distribution is restricted to those actively engaged in engineering or construction. Use the coupon below or write the manufacturer direct, mentioning PUBLIC WORKS.

Construction Materials and Equipment

Air Raid Shelters

3. New 8 page booklet pictures and describes a corrugated pipe shelter with gas tight end walls, emergency escape tunnel and other desirable features. Armco Drainage Products Assn., Middletown, Ohio.

Asphaltic Limestone

5. Characteristics, methods of laying, and results with cold lay mixture shipped ready to use. Especially adapted to resurfacing old pavements, sealcoats and airport runways. Alabama Asphaltic Limestone Co., Liberty Nat. Life Bldg., Birmingham, Ala.

Bridges

7. Teco Connectors, a new method of structural engineering, to spread the load on a timber joint more equally over the cross-section of the wood is described in new literature available from Timber Engineering Co., Inc., Dept. BS-2, 1319-18th St., N. W., Washington, D. C.

8. Lt.-weight, non-skid, mineral surfaced asphalt planks for any type bridge. Write for latest catalog. Serviced Products Corp., 6051 West 65th St., Chicago, Ill.

Cement Dispersion

9. "Economics of Cement Dispersion and Pozzolith" tells the complete story of how cement dispersion reduces water required up to 20% and increases workability 150%. Write The Master Builders Co., Cleveland, Ohio, for a copy.

Cement, Early Strength

11. 64-page manual tells how to speed up year 'round concreting, shows how to secure high early strength and greater workability at temperatures either below or above freezing. Contains many actual examples of practical concreting operations; well illustrated with more than 60 photos, charts, graphs and tables. Calcium Chloride Assn., Penobscot Building, Detroit, Mich.

Cold Mix Plants

15. New catalog and prices of Portable Bituminous Mixers in 6 to 14 ft. sizes for resurfacing and maintenance. Issued by The Jaeger Machine Co., 400 Dublin Ave., Columbus, Ohio.

Concrete Accelerators

31. New 48-page booklet in five sections explains clearly the effects, advantages and methods of using Calcium Chloride and Portland Cement mixes. Complete and packed with practical information; well illustrated; pocket size. Sent free on request by Solvay Sales Corp., 40 Rector St., New York, N. Y.

33. Pocket manual of concrete curing with calcium chloride. Complete, handy. Contains useful tables, well illustrated. Write the Columbia Chemical Division, Pittsburgh Plate Glass Co., 30 Rockefeller Plaza, N. Y. C.

Concrete Mixers

44. Catalog and prices of Concrete Mixers, both Tilting and Non-Tilt types, from 3½ to 56S sizes. The Jaeger Machine Company, 400 Dublin Ave., Columbus, Ohio.

Drainage Products

70. Standard corrugated pipe, perforated pipe and MULTI PLATE pipe and arches — for culverts, sewers, subdrains, cattlepasses and other uses are described in a 48-page catalog entitled "ARMCO

Drainage Products," issued by the Armco Drainage Products Association, Middletown, Ohio, and its associated member companies. Ask for Catalog No. 12.

73. "Principles of Design of Airport Drainage" and other articles on airport drainage reprinted from PUBLIC WORKS Magazine are being distributed free by Bowerston Shale Co., Bowerston, O., Hancock Brick & Tile Co., Findlay, O., and Columbus Clay Mfg. Co., Blacklick, O. Address anyone of the above for a copy.

Graders, Patrol

105. The Austin-Western 99M Power Grader with its powerful all wheel drive simplifies all construction and maintenance; handles difficult jobs with economy and efficiency; and does better work on grading, ditching, scarifying, snow plowing, loading, mixing, bulldozing, shoulder trenching and backsloping. Write for Bulletin 1946. Austin-Western Road Machinery Co., Aurora, Ill.

Mud-Jack Method

107. How the Mud Jack Method for raising concrete curb, gutter, walls and street solves problems of that kind quickly and economically without the usual cost of time-consuming reconstruction activities — a new bulletin by Koehring Company, 3026 West Concordia Ave., Milwaukee, Wis.

Oil

109. Ring-Free Motor Oil that keeps motors clean and free from carbon, and reduces frequency of overhauls is described in literature available from Macmillan Petroleum Corp., 530 West 6th St., Los Angeles, Calif.

Paving Materials, Bituminous

111. New "Tarvia Manual" is packed with useful data on how to build and maintain roads with Tarvia. Each step is illustrated with excellent action pictures, 64 pp. 103 illus. Write to The Barrett Div., 40 Rector St., New York, N. Y.

Pumps

120. Interesting new booklet tells how to lengthen the life of your pumps. Explains how a little care will save a lot of wear. Write today for your copy. Homelite Corp., 2403 Riverdale Ave., Portchester, N. Y.

121. New illustrated catalog and prices of Jaeger Sure Prime Pumps, 2" to 10" sizes, 7000 to 220,000 G.P.H. capacities, also Jetting, Caisson, Road Pumps, recently issued by The Jaeger Machine Company, 400 Dublin Ave., Columbus, Ohio.

123. New brochure by Gorman-Rupp Co., Mansfield, Ohio, illustrates and describes many of the pumps in their complete line. Covers heavy duty and standard duty self-priming centrifugals, jetting pumps, well point pumps, triplex road pumps and the lightweight pumps.

124. 16-page illustrated bulletin, SP-37, describes and illustrates complete

C. H. & E. line of self-priming centrifugal pumps from ½" to 8", including lightweight models for easy portability. C. H. & E. Mfg. Co., 3841 No. Palmer St., Milwaukee, Wis.

Road Building and Maintenance

128. Motor Patrol Graders for road maintenance, road widening and road building, a complete line offering choice of weight, power, final drive and special equipment to exactly fit the job. Action pictures and full details are in catalogs Nos. 253, 254 & 255, issued by Gallon Iron Works & Mfg. Co., Gallon, Ohio.

Rollers

133. New Tu-Ton roller of simple construction for use in rolling sidewalks along highways, playgrounds and other types of light rolling is fully described in a bulletin issued by C. H. & E. Mfg. Co., 3841 No. Palmer St., Milwaukee, Wis.

138. "The Buffalo-Springfield line of road rollers (tandem, 3-wheel, and 3-axle) are described in the latest catalog issued by the Buffalo-Springfield Roller Co., Springfield, Ohio."

139. "Ironroller" 3 Axle Roller for extra smooth surfaces on all bituminous work. Booklet contains roller data and operation details. Hercules Co., Marion, Ohio.

140. This well-illustrated 16-page catalog describes the tandem, autocrat, cadet, and roll-a-plane rollers, and explains what each is intended to accomplish. Write Austin-Western Road Mach. Co., Aurora, Ill.

Soil Stabilization

150. "High-Service, Low Cost Roads" is one of the newer booklets using an effective combination of picture and text to set forth the principals and advantages of road surface stabilization with calcium chloride. Complete, interesting and well illustrated. 34 pages. Sent by Solvay Sales Corp., 40 Rector St., New York, N. Y.

152. The Columbia Chemical Division will be glad to furnish to anyone interested complete information dealing with Calcium Chloride Stabilized Roads. This literature contains many charts, tables and useful information and can be obtained by writing Columbia Chemical Div., Pittsburgh Plate Glass Co., 30 Rockefeller Plaza, New York City.

154. "Soil Stabilization with Tarvia" — An illustrated booklet describing The steps in the stabilization of roadway soil with Tarvia will be mailed on request by The Barrett Div., 40 Rector St., New York, N. Y.

Spreader

187. Jaeger Paving equipment, including Mix-in-Place Roadbuilders, Bituminous Pavers, Concrete Bituminous Finishers, Adjustable Spreaders, Forms, etc. — 4 complete catalogs of latest equipment in one cover, issued by The Jaeger Machine Company, 400 Dublin Ave., Columbus, Ohio.

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189. "Typical Designs of Timber Structures" contains plans for 45 representative structures that have been engineered with Teco Connectors. For free copy write Timber Engineering Co., Inc., Room 6GG, 1319-18th St., N. W., Washington, D. C.

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198. Illustrated Bulletins 15 to 20 describe Mohawk Oil Burning Torches; "Hot-stuff" Tar and Asphalt Heaters; Portable Trailer Tool Boxes; Pouring Pots and other equipment for street and highway maintenance, roofing, pipe coating, water proofing, etc. Mohawk Asphalt Heater Co., Frankfort, N. Y.

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210. "How to Maintain Roads with Dowflake" is a new 58 page illustrated booklet of information on stabilized road construction. Includes specifications and several pages of reference tables from an engineer's notebook. Issued by Dow Chemical Co., Midland, Mich.

212. "Are You Annoyed by Dust?" an illustrated circular telling how to prevent dust with calcium chloride. Sent free by Michigan Alkali Co., 60 East 42 St., New York, N. Y.

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350. "Frink One-Way Sno-Plows" is a four page catalog illustrating and describing 5 models of One-Way Blade Type Sno-Plows for motor trucks from 1½ up to 8 tons capacity. Interchangeable with V Sno-Plow. Features, specifications and method of attaching. Carl H. Frink, Mfr., Clayton, 1000 Islands, N. Y.

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351. "Make Icy Highways Safe for Traffic"—a new bulletin by Michigan Alkali Co., Ford Bldg., Detroit, Mich., tells how to use calcium chloride for modern ice control.

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356. "Results Produced by Aero-Filters" is a new pamphlet covering results at Temple, Texas; Paris, Ill.; Webster City, Iowa; and Mason, Mich. Write Lakeside Engineering Corp., 222 West Adams St., Chicago, Ill.

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391. See listing No. 410.

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406. New bulletin illustrates Builders Air Relay system of transmission for the Venturi Meter which is particularly useful for liquids containing suspended solids like sewage. Eliminates corrosion, clogged pipes, etc. Write Builders-Providence, Inc., Coddling St., Providence, R. I.

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408. Handbook of Universal Cast Iron Pipe and Fittings, pocket size, 104 pages, illustrated, including 14 pages of useful reference tables and data. Sent by The Central Foundry Co., 386 Fourth Ave., New York, N. Y.

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414. Two new illustrated booklets, "Transite Pressure Pipe" and "Transite Sewer Pipe" deal with methods of cutting costs of installation and maintenance of pipe lines and summarize advantages resulting from use of Transite pipes. Sent promptly by Johns-Manville Corp., 22 East 40th St., New York, N. Y.

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417. Generously illustrated booklet describes McWane 2-inch cast iron pipe and its manufacture in streamlined pipe shop. Write McWane Cast Iron Pipe Co., Birmingham, Ala.

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420. Installation views and sectional scenes on Layne Vertical Centrifugal and Vertical Turbine Pumps fully illustrated and including useful engineering data section. Layne Shutter Screens for Gravel Wall Wells. Write for descriptive booklets. Advertising Dept., Layne & Bowler, Inc., Box 186, Hollywood Station, Memphis, Tenn.

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430. The most complete catalog we have seen on setting and testing equipment for water meters—exquisitely printed and illustrated 48-page booklet you should have a copy of. Ask Ford Meter Box Co., Wabash, Ind.

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431. Data on how large reservoirs may be built at a saving as units by the Wm. S. Hewett System of reinforced concrete construction will be sent without obligation. The Wm. S. Hewett System, 20 N. Wacker Dr., Chicago, Ill.

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434. Be assured of uninterrupted, constant automatic removal of screenings. Folder 1587 tells how. Gives some of the outstanding advantages of "Straightline Bar Screens" (Vertical and Inclined types). Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill.

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440. "Disposal of Municipal Refuse." Complete specifications and description including suggested form of proposal; form of guarantees; statements with diagrammatic outline of various plant designs. 48 pages. Address: Morse Boulger Destructor Co., 216-P East 45th St., New York, N. Y.

442. Recuperator tubes made from Silicon Carbide and "Fireclay" Corebust-ers for maximum efficiency are described and illustrated in bulletin No. 11 issued by Fitch Recuperator Co., Plainfield National Bank Bldg., Plainfield, N. J.

443. Nichols Herreshoff incinerator for complete disposal of sewage solids and industrial wastes—a new booklet illustrates and explains how this Nichols incinerator works. Pictures recent installations. Write Nichols Engineering and Research Corp., 60 Wall Tower, New York, N. Y.

Softening
444. This folder explains the process of Zeolite water softening and describes and illustrates the full line of equipment for that purpose made by the Graver Tank & Mfg. Co., 4809-15 Tod Ave., East Chicago, Ind. Write for a copy of this instructive folder.

Sprinkling Filters
445. Design data on sprinkling filters of Separate Nozzle Field and Common Nozzle Field design as well as complete data on single and twin dosing tanks, and the various siphons used in them, for apportioning sewage to nozzles. Many time-saving charts and tables. Write Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

Swimming Pools
446. Data and complete information on swimming pool filters and recirculation plants; also on water filters and filtration equipment. For data prices, plans, etc., write Roberts Filter Mfg. Co., 640 Columbia Ave., Darby, Pa.

Taste and Odor Control
449. "Taste and Odor Control in Water Purification" is an excellent 92-page, illustrated booklet covering sources of taste and odor pollution in water supplies and outlining the various methods of treatment now in use. Every water works department should have a copy. Write Industrial Chemical Sales Div., 230 Park Ave., New York, N. Y.

450. Technical pub. No. 207 issued by Wallace & Tiernan Co., Inc., Newark, N. J., describes in detail taste and odor control of water with BREAK-POINT Chlorination, a method of discovering the point at which many causes of taste may be removed by chlorination with little or no increase in residual chlorine. Sent free to any operator requesting it.

451. Powdered Hydrosarco for taste and odor control. For complete data on its use write Darco Corp., 60 East 42nd St., New York, N. Y.

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453. "Safe Sanitation for a Nation," an interesting booklet containing thumbnail descriptions of the different pieces of P.F.T. equipment for sewage treatment. Includes photos of various installations and complete list of literature available from this company. Write Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

455. New booklet (No. 1642 on Link-Belt Circuline Collectors for Settling Tanks contains excellent pictures; drawings of installations, sanitary engineering data and design details. Link-Belt Company, 2045 W. Hunting Park Ave., Philadelphia.

456. New 16-page illustrated catalog No. 1742 on Straightline Collectors for the efficient, continuous removal of sludge from rectangular tanks at sewerage and water plants. Contains layout drawings, installation pictures, and capacity tables. Address Link-Belt Co., 2045 West Hunting Park Ave., Philadelphia, Pa.

457. New illustrated folder (1942) on Straightline apparatus for the removal and washing of grit and detritus from rectangular grit chambers. Address: Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

458. "Sedimentation with Dorr Clarifiers" is a complete 36-page illustrated catalog with useful design data. Ask The Dorr Company, 570 Lexington Ave., New York, N. Y.

459. A combination mechanical clarifier and mechanical digester, The Dorr Clarigester, is explained and illustrated in a bulletin issued by The Dorr Company, 570 Lexington Ave., New York, N. Y.

461. Preflocculation without chemicals with the Dorco Clariflocculator in a single structure is the subject of a new booklet issued by The Dorr Company, 570 Lexington Ave., New York, N. Y.

462. Dorco Monorake for existing rectangular sedimentation tanks, open or closed, is described and illustrated in a new catalog sent on request. The Dorr Co., 570 Lexington Ave., New York, N. Y.

Valves (See Gates, Air Release, etc.)

Waste Elimination

469. Full information on the Pitometer Survey—a complete check-up on your water plant to reveal hidden sources of waste—will be sent promptly by The Pitometer Co., 48 Church St., New York, N. Y.

Water Treatment

470. If you have a water conditioning problem of any kind, write Graver Tank & Mfg. Co., Inc., 4809-15 Tod Ave., East Chicago, Ind., who manufacture all types of conditioning equipment and will be pleased to make recommendations.

471. Lime specifications and full impartial data on water treatment with lime may be obtained from National Lime Assn., 927 Fifteenth St., N. W., Washington, D. C.

472. Bulletin describes stabilizing lime-softened water by recarbonation, discussing gas production, washing, com-

pressing, drying, and applying the CO₂. International Filter Co., 325 West 25th Place, Chicago, Ill.

473. Water Softening. The use of the Spaulding Precipitator to obtain maximum efficiency and economy in water softening is described in a technical booklet. Permutit Co., 330 W. 42nd St., New York, N. Y.

Water Works Operating Practices

490. "Important Factors in Coagulation" is an excellent review with bibliography and outlines of latest work done in the field. Written by Burton W. Graham and sent free on request to Stuart-Brumley Corp., 516 No. Charles St., Baltimore, Md.

Water Service Devices

500. Data on anti-freeze outdoor drinking fountains, hydrants, street washers, etc., will be sent promptly on request to Murdock Mfg. & Supply Co., 426 Plum St., Cincinnati, Ohio.



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LETTERS to the Editor

Wants Every Issue Hammond, La.

Every now and then I get a copy of PUBLIC WORKS and always find something valuable to me; in the May issue—Vol. 73 No. 5—there are articles on pages 19 and 28 that are very helpful.

We take a great many magazines but I am going to add your good Journal to the list, and will ask that you enter my subscription for one year, and send same to me until further notice.

Send me the bill and I will mail check.

With best wishes, I am,
Very respectfully,
HENRY A. MENTZ

Operation of Water Treatment Plants In Portuguese REPARTICAO DE AGUAS E ESGOTOS

Sao Paulo, Brasil

We have read in the April 1938 issue of PUBLIC WORKS the very interesting article "The Operation of Water Treatment Plants," prepared by W. A. Hardenbergh and consulting staff.

The Water and Sewerage Department of the City of Sao Paulo publishes periodically a magazine, in which we have already inserted translated in Portuguese the article "The Operation of Sewage Treatment Plants" having sent you 6 copies of our publication containing that translation.

We will appreciate very much to have your kind permission to translate this new article to be inserted in our next publication.

HIPOLITO SILVA

Editor's Note: Glad to grant it.

More Engineer Officers Needed by the Sanitary Corps

The demands for sanitary engineers for duty with the Sanitary Corps continue to increase. Within the next few months, it is expected that some 200 additional men will be needed. Qualified engineers will be commissioned in the Sanitary Corps and assigned to duty in camps or with troops in this country and overseas. Their duties will comprise supervision of water supplies, waste disposal and mosquito and other insect control measures.

Minimum qualifications are an engineering degree from an approved college or school and four years of satisfactory experience. A limited number of appointments will be made in the grade of captain, these being restricted to men with exceptional qualifications; the great majority of acceptable applicants will be commissioned in the grade of first lieutenant. All applicants must pass the Army physical examination. Full details can be obtained by writing Major J. J. Gilbert, San. Corps, Office of the Surgeon General, U. S. Army, Washington, D. C.

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Albright & Friel, Inc.	77
Alvord Burdick & Howson	77
Anthracite Equipment Corp.	60
Armco Drainage Products Assn.	5
Barrett Div., The	8
Black & Veatch	77
Briggs & Stratton Corp.	59
Browne, Floyd G.	77
Buck, Seifert & Jost	77
Buffalo-Springfield Roller Co.	65
Builders-Providence, Inc.	29
Cafe Monaco	75
Caird, James M.	77
Calcium Chloride Assn.	3
Central Foundry Co., The	35
C. H. & E. Manufacturing Co.	82
Continental Hotel	68
Darco Corporation	45
DeWitt Hotels	73
Dorr Co., The	10
Dow, A. W., Inc.	77
Fitch Recuperator Co.	70
Ford Meter Box Company	84
Frink Mfr., Carl H.	68
Gallon Iron Works & Mfg. Co.	85
Gannett, Eastman & Fleming, Inc.	77
Goff, William A.	77
Gorman-Rupp Company	73
Graver Tank & Mfg. Co.	57
Greeley & Hansen	77
Green Co., Howard R.	77
Hewett System, The Wm. S.	75
Homelite Corp.	79
Industrial Chemical Sales Div.	39
Infilco, Inc.	31
Jaeger Machine Co.	65 & 67
Jeffrey Mfg. Co.	71
Johns-Manville Corp.	42 & 43
Koehring Co.	67
Layne & Bowler, Inc.	6
Link-Belt Co.	76
Littleford Bros., Inc.	66
Macmillan Petroleum Corp.	4
Master Builders Co., The	2
Mathieson Alkali Works, Inc.	47
McWane Cast Iron Pipe Co.	75
Metcalf & Eddy	77
M. & H. Valve & Fittings Co.	63
Mohawk Asphalt Heater Co.	68
Morse Boulder Destructor Company	71
Murdock Mfg. & Supply Co.	84
National Fireproofing Corp.	70
National Lime Assn.	56
National Water Main Cleaning Co.	49
Omega Machine Co., Inc.	61
Pacific Flush Tank Company	71
Permutit Co., The	37
Pirnie, Malcolm	77
Pitometer Co., The	58
Pittsburgh Equitable Meter Co.	51 & 52
Proportioners, Inc.	54
Robert & Co., Inc.	77
Roberts Filter Manufacturing Co.	25
Russell & Axon Cons. Engrs., Inc.	77
Servicised Products Corp.	80
Simplex Valve & Meter Co.	33
Snell, Inc., Foster D.	77
Solvay Sales Corp.	41
South Bend Foundry Co.	82
Stewart, W. H.	76
Stuart-Brumley Corp.	74
Taylor & Co., W. A.	60
Toquet, Frederick E.	77
Timber Engineering Co., Inc.	9
Wallace & Tiernan Co., Inc.	Back Cover
Wood Co., R. D.	83



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